Microscopic Study on Size and Roundness of Some Malaysian Sand for Proppant

By

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Dissertation submitted in partial fulfillment of

the requirement for the

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(PETROLEUM ENGINEERING)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

(AP DR Nasiman Bin Sapari)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the reference and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

(Abdul Nasir Bin Mohamad Sobri)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2013

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ABSTRACT

The significant of proppants are really important in oil and gas operations worldwide. Proppants will always be needed in any hydraulic fracturing job. However, currently in Malaysia there is no local proppants producer exists although there are a lot of oil and gas field being operated. Besides, the sands in Malaysia also were not fully characterized for proppants. There is an opening to look for a suitable material to be used as a proppants in Malaysia. This is because the most of the material or sand that are currently being used for proppants exist in Malaysia. Hence, this project aims to characterize some of Malaysian sand in term of its size and roundness. At the same time, to provide any suggestion in order to improve the quality of sand for proppant if there is any. Comprehensive literature review have been conducted to identify the concept and scope of study to be consider to achieve the objectives, which are; i) hydraulic fracturing, ii)selection of proppants, iii) physical characteristic of proppants, iv) location of suitable sand sample considering its type and mineralogy of sand. On the other hand, to conduct this project successfully, the author also did searches through journal paper and technical books to identify the methodology. By utilizing the methods that have been mentioned by several literatures, the author will first collect sample from an area identified to have suitable sands which is Terengganu. The sample then will be used in laboratory experiment to determine its characteristic. The laboratory experiments involve sieve analysis, roundness and sphericity test and permeability. The experiments aim to characterize the sand samples that have been collected. Ultimately, suggestion for further study on related matter is made based on the finding especially in the area of standard proppant testing and improvement of proppant properties.

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CHAPTER 1: PROJECT BACKGROUND

1.1 Background of study

In Oil and Gas industries, well stimulation technique is a common job carried out by various companies operating the oil and gas field in order to increase production. Most of the large and high permeability reservoirs are now coming close to maturity and abandonment. People are aggressively pursuing for the reservoir which have a good and economical reserve although the permeability are quite low. Here in this case, well stimulation technique will come into picture. They are several types of well stimulation technique exist in the industries. Two types of techniques that are commonly used are hydraulic fracturing and acid fracturing.

In this project, our concern lies on the hydraulic fracturing technique for the well stimulation. Hydraulic fracturing is a well stimulation method specially performed on reservoirs with low permeability to ease the flow of hydrocarbon into wellbore. Specially engineered fracturing fluid is pumped into the well or desired fracturing area at flow rate and pressure high enough to create two opposing horizontally crack in the target formation . After the cracks are created, propping agent called proppants are inserted into the fracture. The main functions of the proppants are to maintain the fracture open and provide conductivity and permeability. Most of the time, the material for the proppants are treated silica sand (Beckwith, 2011).

For the proppant to be funtioning effectively, there are several criteria outline by various operating company based on experience on the field and research. Some of the criteria include size of the proppant particle, roundness, crush resistance or ability to withstand high closure stress, geochemical and diagenetic reaction resistance, porosity, permeability and conductivity (Cohen, et al., 2013) (Terracina, Turner, Collins, & Spillars, 2010) (Beckwith, 2011). Our focus will be on two of the above criteria ; size and roundness.

In Malaysia, there are abundant of natural silica and they are devoted to the country's glass-making and construction industry (Kwan, 2006). There is an opportunity to look into these local sand as a candidate to be used as commercial proppant. There are no local proppant producer and supplier in Malaysia up to now (Mohd Saaid, Kamat, & Muhammad, 2011). Because of that, oil and gas company operating in Malaysia have no choice but to acquire the proppant from supplier in other country. Thus, the cost and time for the stimulation job become higher. The production of proppant locally could become an alternative. To date, silica sand based proppant is the most commonly used proppant since it is the most common mineral in Earth continental crust and due to its properties compare to other mineral (Beckwith, 2011) (Mohd Saaid, Kamat, & Muhammad, 2011). Abundant resource of natural silica in Malaysia show a potential of producing proppant locally.

1.2 Problem Statement

1.2.1 Problem Identification

Up to now, there is no local producer for proppants in Malaysia. There are abundant resource of silica sand and hence gave an opportunity to produced silica based proppants locally. If the proppants can be produced locally, the cost and time for stimulation job can be reduced and at the same time boost the Malaysia's economy. However, there are several criteria need to be assessed on those sand in order to be used as a proppants. Among all the criteria, the project focuses on the two most important criteria that are size and roundedness. These criteria are significance in providing the proppants pack its porosity, conductivity and permeability. As for other factor, alteration and treatment to the sand can be made as what has been practice by the industries such as resin coating to handle proppants flow back problem.

This project is conducted to collect some possible sand around Malaysia and carry out microscopic study on size and roundedness of the samples collected.

1.2.2 Significance of Project

This research is very significant as the result will give the result on possible use of Malaysia's sand as commercial proppants. There are various types of natural resources of sand and will be a waste if it is not fully utilized. Once the results have been obtained, further research on other factor of proppants can be conducted.

1.3 Objective and Scope of Study

1.3.1 Objective

The research goal is to understand and investigate the size and roundedness of some Malaysian Sands for possible use as proppants on microscopic level. Further possible improvement and treatment on the sand will be found out during the research conducted. Hence, this research aims to;

1. Characterize some of Malaysian sand in term of its size and roundness
2. Investigate the suitability of Malaysian sand for proppants in term of its size and roundedness.
3. To provide suggestion to improve the properties of the sand for proppant – If there is any.

1.3.2 Scope of Study

In overall, the research plan is to evaluate the size and roundedness of sand sample taken from several places in Malaysia and to investigate its suitability to be used as proppants. Although there are many other criteria that should be given concern such as its crush resistance and geo-chemical properties, these criteria will be given less priority due to time limitation of the project. Hence the factors that are taken into account in this research;

1. Hydraulic Fracturing.
2. Selection of Proppants.
3. Desired particle size and roundedness of sand for proppant and method of improvement.
4. Location of suitable sand sample and its type or mineralogy.

1.4 Relevancy of the Project

This research will be very relevant judging from certain criteria and circumstances. From the project background, this research focuses on microscopic study on size and roundedness of Malaysian sand for proppant.

In production of hydrocarbon, it is common for the operator to conduct such stimulating job. As a petroleum engineering student, this matter is very important and will provide a strong basic for the author to involve in Well Stimulation Technique area. In the future, the knowledge and experience will be very meaningful.

1.5 Feasibility of the Project within the Scope and Time Frame

In term of the scope, the project is feasible since all the scope of studies is achievable as it is within the knowledge and experience of the author and the supervisor. Besides, improvement also can be made from researches from literature and guidance from technical professional.

Meanwhile, in term of time, the project is feasible as the time allocated for this final year project is approximately 28 weeks. With careful and detail planning, the project can be carried out successfully.

CHAPTER 2: LITERATURE REVIEW

2.1 Hydraulic Fracture

From the first intentional hydraulic fracture stimulation of a reservoir in the late 1940s, engineers and scientists have sought to understand the mechanics and geometry of hydraulically created fractures. Hydraulic fracture is a process where specially engineered fracturing fluid is pumped into the well or desired fracturing area at flow rate and pressure high enough to create two opposing horizontally crack in the target formation (Tiemann, Andrews, Copeland, Folger, Brougher, & Meltz, 2012) (Keshavarzi & Mohammadi, 2012) (Ali, 2010). The purpose of hydraulic fracturing is to increase permeability, connect to natural fracture, increase contact area and ultimately maximize production (Ali, 2010) (Zhou, 2011) (S. Al Rbeawi, 2012).

In order to fracture a reservoir, understanding of the characteristic of the reservoir itself is inevitable. Designing a hyraulic fracture should be carried out with full detail. From high permeability reservoir to low permeability reservoir, the design of the fracture treatment should differ taking into consideration of the condition (Subhash, Vincent, Robert, & Terry, 2010).

Sierra, Mayerhofer, & Jin (2013) have outline several factors that control improvement in productivity provided by hydraulic fracturing which are effective fracture half length, relative differences in fracture and formation flow capacity, and proppant distribution. Meanwhile, Jabbari & Zheng (2012) describe the parameters that will influence hydraulic fracturing are fracturing fluid & volume, proppants type & size, fracture half-length, fracture stage and lateral length. In the same time, Armirola *et al* (2011) also describe the factors to be effective half- length and fracture conductivity.

Hence, the key factor can be summarise as follow;

- Effective fracture half length
- Fracture Conductivity
- Proppants and fluid characteristic
- Proppants distribution and settling

After the fracture have been created, the effectiveness of the fracture also need to be evaluate. In evaluating the effetiveness, the key factor summarise above will come into picture. Therefore, the factor that can be calculate are (Rahim, et al., 2012) (Vincent, 2009);

- <u>Dimensionless Fracture Conductivity</u>

  It enable us to understand the amount of conductivity in fracture by varying permeability and fracture length.

- $F_{CD} = \frac{k_f\, w}{k\, x_f}$

  Dimensionless fracture conductivity (F_{cd}) as fracture conductivity, k_{fw} (md-ft), divided by reservoir permeability (k) times fracture half-length, x_f (ft) (see equation). F_{cd} enables us to understand the amount of conductivity in a fracture by varying permeability and fracture length.

- <u>Fold of Increase (FOI)</u>

  FOI is related to "Productivity Index"- PI in a ratio of fractured versus natural completion. Value of FOI can be calculated by determining the flow rates before and after a fracture stimulation treatment (FOI= Q_f /Q_{nat}).

$$FOI = \frac{\ln({r_e}/{r_w})}{\ln\left({r_e}/{r_w'}\right)+s}$$

  where "r_e" is drainage radius, "r_w" is wellbore radius, "s" is prefrac skin, and "r_w'" is the equivalent wellbore radius . Values for FOI can vary from 1, meaning no stimulation, to values > 10 for being very stimulated.

2.2 Selection of Proppant

Selection of a suitable and appropriate proppant can ensure the successful of fracture treatment. The selection may depend on the quality of the reservoir and fracture design. Currently, there are abundant of proppant type and characteristic that can be choose. Some of the famous proppant type that are being used by the industry are (Ali, 2010) ;

- Ottawa sand
- Bauxite
- Resin Coated Sand
- Low Density Proppant

Figure 1 : Famous proppants type

Dingwei, Qun, Ziyi, & Yong (2012) mention that the conductivity of proppants itself will affect the effectiveness of fracture and the conductivity also should be able to last long. In another paper, Penny, Zelenev, Champagne, & Crafton (2012) also stated the same about how the effectiveness of fracture depends on the conductivity of the proppant. Although the chosen proppant may have a high degree of conductivity, if they cannot withstand the condition of reservoir, the proppant will lose its conductivity as time pass (Raysoni & Weaver, 2012). The conductivity associated with different proppants varies with the proppant, and with the proppant stress of the formation (Vincent, 2009) as seen in Figure 1.

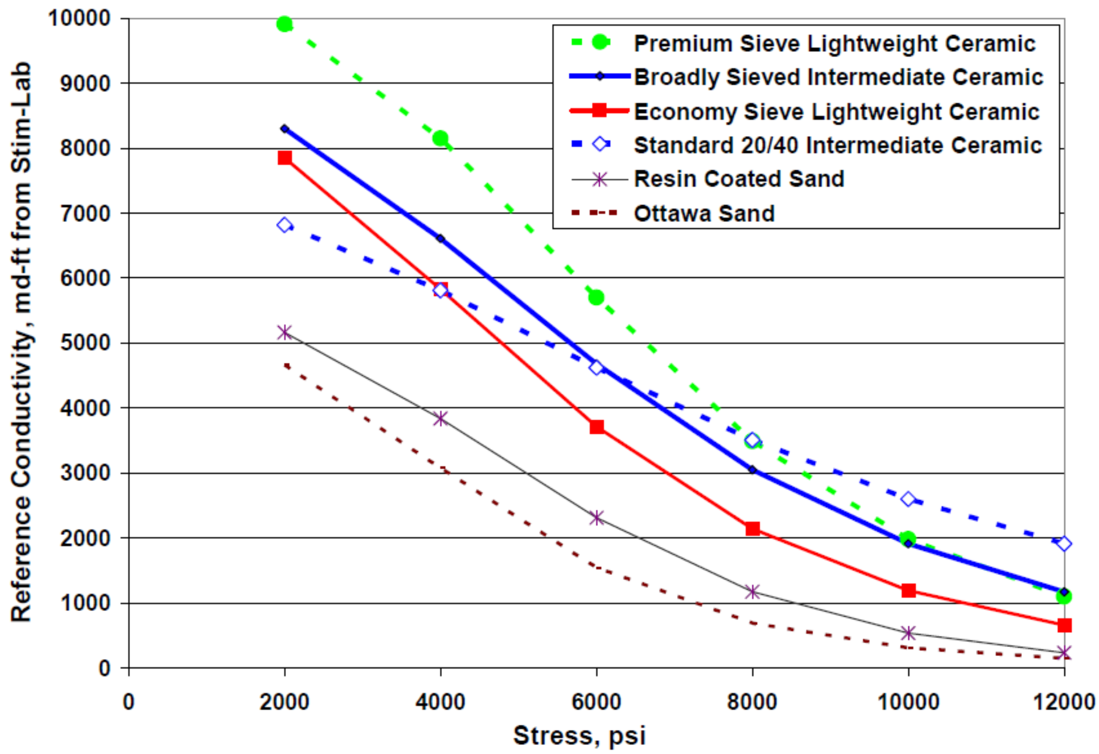


Figure 2 : Graph of Stress versus conductivity for several type of proppants (Vincent, 2009)

On top of that, J. Edelman (2013) explained that the proppant used in hydraulic fracturing need to be effectively transportable into the fracture, compatible with the fracture and wellbore fluids, resist flowback and thermally & chemically stable. In another paper, Raysoni & Weaver (2012) also highlighted that how important a proppant to be able to withstand the closure stress and diagenetic process in respective reservoir. Diagenesis is a process where conversion of high-porosity granular material into low-porosity rock take place. The same thing on how closure stress resistance of proppants will determine the conductivity of the fracture also being mentioned over and over again by several other author (Cohen, et al., 2013) (Penny, Zelenev, Champagne, & Crafton, 2012) (Beckwith, 2011)(Don Lyle, 2011).

Besides that, the proppant pack embedment also will affect closely on the fracture conductivity (Alramahi, 2012) (Gao, 2012) . Proppant embedment is a process where the proppants particle settle down and fix firmly in the fracture space. On the other hand, there also need to be a balance between the density and concentration of proppant in order to ensure that the fracture will have a high conductivity (Parker, 2012) (Liu, 2012).

2.3 Physical properties of proppant

When mention about proppant that being used in hydraulic fracturing, of course there are several properties of the proppant that we should look into. Thus, author has done a literature review from several papers in order to understand the important physical properties of proppant that are need attention. The summary of the physical properties are as below;

(1) Particle size: Particle size has a significant impact on proppant pack permeability. Coarse proppant will result in higher flow conductivity but may crush under stress (Beckwith, 2011).

(2) Proppant concentration: The proppant concentration refers to the mass of proppant per unit area of fracture placed by the treatment. It is usually expressed in lb/ft^2 or kg/m^2. Generally, a high viscosity and high proppant concentration will bring a success due to its ability to create a wide fracture. Concentrations of proppant will give effect on proppants transport and its composition may be unique depend on the fracturing design. An accurate amount of concentration will ensure the transport of proppant in the fracture without bridging (Nicholas & Guanshui, 2011) (Parker, 2012).

(3) Proppant strength: A proppant with high strength will be able to withstand high closure pressure and still hold the fracture opens (Don Lyle, 2011). Hence, fracturing of deeper formations requires the use of stronger proppant materials. Sintered bauxite, a ceramic proppant, is one of the hardest materials known able to withstand high pressure (Beckwith, 2011) (Alramahi, 2012).

(4) Proppant Density : In term of density, the proppant is normally characterizes by two parameters which are apparent specific gravity (ASG) and bulk density (BD) (Freeman, Anschutz, Renkes, & Milton-Tayler, 2006). Lower density (78-125 lbs/ft^3) proppants material will be an advantage over denser material. At low stresses, proppant with lower density will create wider fracture with highest conductivity (Vincent, 2009) (Alramahi, 2012) (Parker, 2012).

(5) Proppant Grain Shape: Roundness and sphericity are important properties because they influence the porosity and packing of the proppant pack (Mohd Saaid, Kamat, & Muhammad, 2011). Grain roundness is a measure of the relative sharpness of grain corners, and particle sphericity is a measure of how closely the grain approaches the shape of a sphere (PropTester, 2009).

2.4 Particle Size and Roundness

Since this project will be focusing more on the proppants particle size and roundness, detail investigation and literature review was done in order to understand better on the topic. It is important for us to understand what factor will be influences by different proppant size and roundness. After doing review from several literature, the following are the compilation of the factor that will be influenced by proppant size and roundness;

- *Proppent Embedment*
  (Gao, 2012)
- *Proppant Conductivity, Porosity, and Permeability*
  (Beckwith, 2011) (Cohen, et al., 2013) (Terracina, Turner, Collins, & Spillars, 2010) (Ali, 2010) (Alramahi, 2012)
- *Closure Stress Tolerance*
  (Cohen, et al., 2013) (Terracina, Turner, Collins, & Spillars, 2010) (Gao, 2012)
- *Flowback Problem*
  (J. Edelman, 2013)

Based on literature written by Mohd Saaid, Kamat, & Muhammad (2011), the desired roundness of proppant is 0.7 (Krumbein Chart) and the desired size for the proppant is 0.41-0.72 mm (diameter).

Rod Shaped particle proppants vs Spherical Particle Proppants

The conventional proppants widely being used are nornally using spherical particle proppant. However, based on Kayumov, et al. (2012) and J. Edelman (2013) a rod shaped proppants will provide better performance in hydraulic fracturing especially in term of flowback control problem. The rod shaped proppants have been used by the industries since 2009 in Middle East. It is synthetically done from bauxite and aluminium. Due to its shape, the proppants pack will have higher stability and prevent them from from backward during back flush or production. Kayumov, et al. (2012) describe that the high three point bending strength is the source of the pack stability.

Although the rod shaped proppants provide superior properties, there exist a disadvantage when compare to sphere proppants. The disadvantage is that the rod shaped proppants need to be made synthetically, while sphere proppant mostly can be readily obtain in large amount from nature. Therefore, in term of economics, the sphere particle can be consider better. Besides, the rod shaped proppant also is not being widely used yet except for several places such as middle east and russia. Hence, the technology is not fully develop yet. Despite all that, rod shaped proppants still is a good alternatives to be used for hydraulic fracturing in the future.

CHAPTER 3: METHODOLOGY

3.1 Research Methodology

The methodology of the research is explained in Figure 4. This methodology explains the flow of the research for the whole project duration (FYP1 & FYP2) in general flow. In other words, this methodology will be the guideline, to ensure the research to be executed in a manageable approach in term of time, cost, and feasibility of the research itself.

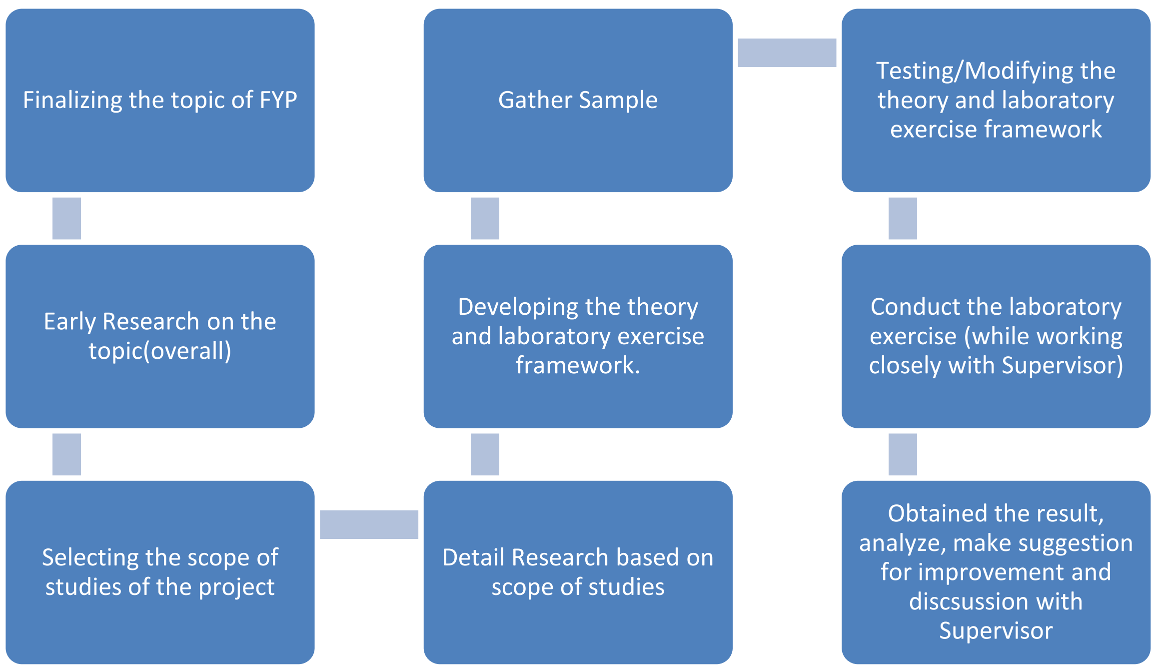


Figure 3 : General Research Methodology

3.2 Project Activities

Sample Gathering

The sample for this project is taken from five different location at Terengganu state. The locations are as follow;

Figure 4 : Overall Map for Sampling Location

Continuous sampling was done for an average distance of 1km from land toward the sea. Several samples were taken from each location. The depth (from surface) at which the sand taken were recorded. Besides, the coordinate of the sampling spot also was recorded for documentation and mapping purpose. The sketch layout of the location also was carried out in order to understand the geological structure of the sampling location. Finally, a map was build based on the coordinate taken in order to observe the sampling direction and the distance between each sampling spot.

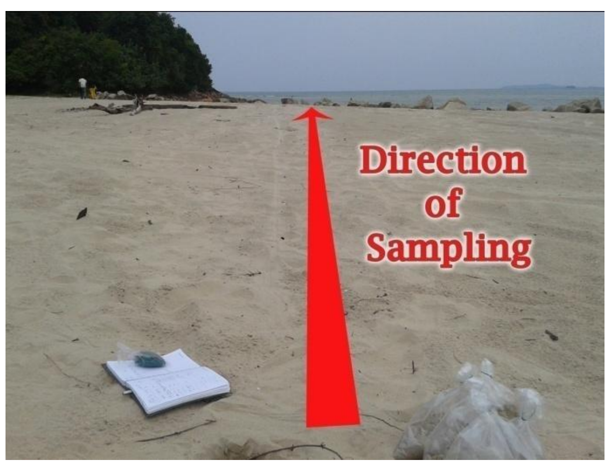


Figure 5 : Direction of Sampling

The summary on the sampling data can be found on the following table;

Location	Spot	Depth (cm)	Coordinate	Location Layout	Location Map
Cherating	S1	20	4.12482548	Appendix III	Appendix II
			103.3974308		
	S2	10	4.1249286		
			103.3973826		
	S3	10	4.12499647		
			103.3973449		
	S4	10	4.12499894		
			103.3973423		
	S5	10	4.12513473		
			103.3972769		
	S6	10	4.12587967		
			103.3960944		
Rantau Abang (South)	S1	10	4.84903233	Appendix III	Appendix II
			103.4017425		
	S2	10	4.84898337		
			103.4017364		
	S3	10	4.84898872		
			103.4016628		
	S4	10	4.84950004		
			103.4020966		
	S5	10	4.84991361		
			103.4024986		
Rantau Abang	S1	20	4.86730204	Appendix III	Appendix II
			103.3936725		
	S2	10	4.8673236		
			103.3935798		
	S3	10	4.86725826		
			103.3934927		
Rantau Abang (North)	S1	10	4.92963939	Appendix III	Appendix II
			103.3575966		
	S2	10	4.92959843		
			103.3575417		
	S3	10	4.92943639		
			103.3572114		
Marang	S1	20	5.161087	Appendix III	Appendix II
			103.234025		
	S2	10	5.161065		
			103.234169		

Table 1 : Sampling Data

Sieve Distribution and Particle Sizes

Sieve analysis will be conducted on the sample in order to obtain the sand particle sizes distribution. Sample is dried to a constant weight at a temperature of 110±5 ºC. Then, suitable sieve sizes are nested in decreasing order of size where the pan is placed below the bottom sieve. The sample is placed on top sieve and lid is put over top sieve. The sieve are agitated by sieve shaker for 10minutes. The weight of material retained is determined on each sieve. The percentages of passing and total of percentages retained are calculated and sieve distribution graph is plotted.

Roundness and Sphericity test

For the roundness and sphericity test, the samples to be tested are selected based on the result obtained from particle distribution size analysis. The samples from different locations are observed and the one that show the closer result to the interested size (20/40 Mesh Size or 400 microns - 841 microns) are selected.

The sand particle is observed under the Meiji Polarizing Microscope that is attached with a camera. The magnification is adjusted until the image is clear when viewed under the microscope lens. Then, by using the attached camera and ToupView software, the image of the sand grain is captured and saved. In order to make the result is representative for the sample; approximately 30 grains of sand images are captured and saved. The magnification used when viewing the sand grains is then recorded. Next, all of the images of the sand grains are printed on an A4 paper.

In this project, the author used manual hand calculation to calculate the roundness and sphericity of the samples. The formulas and methods to obtain the result are adapted from Stratigraphy and Sedimentation 2nd Edition by Krumbein & Sloss (1963). The formula to determined sphericity and roundness of the sand grains are as followed:

$$\text{Operational Sphericity} = \frac{d}{a}$$

Where; d = nominal diameter

a = maximum intercept through the particle

$$\text{Roundness} = \frac{Average\ \ radius\ \ of\ \ corners\ \ and\ \ edges}{Radius\ \ of\ maximum\ \ \ inscribed\ \ \ circle}$$

A set of circles are drawn on a tracing paper with various radius starting from the smallest (1.5mm) to the largest (40mm). The image of each sand grains that has been printed is then compared with the circle in the tracing paper in order to get all the parameters required to calculate the roundness and sphericity of the particle as mentioned above.

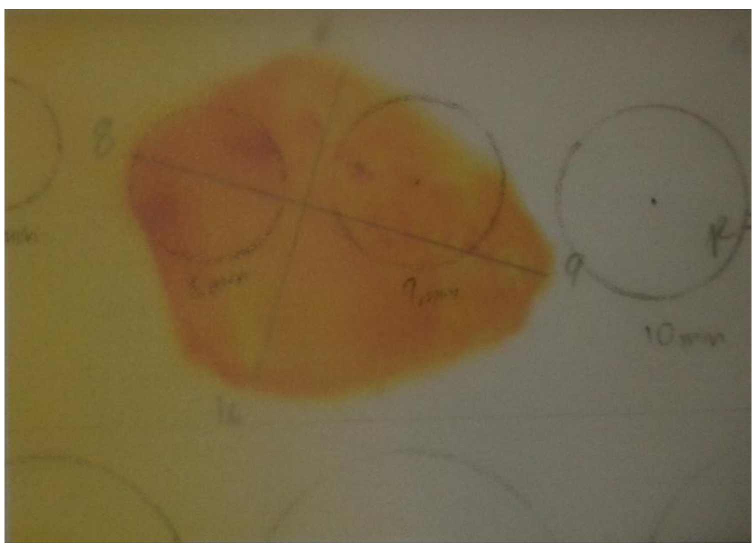


Figure 6 : Example calculation for the radius of corners and edge of sand grain

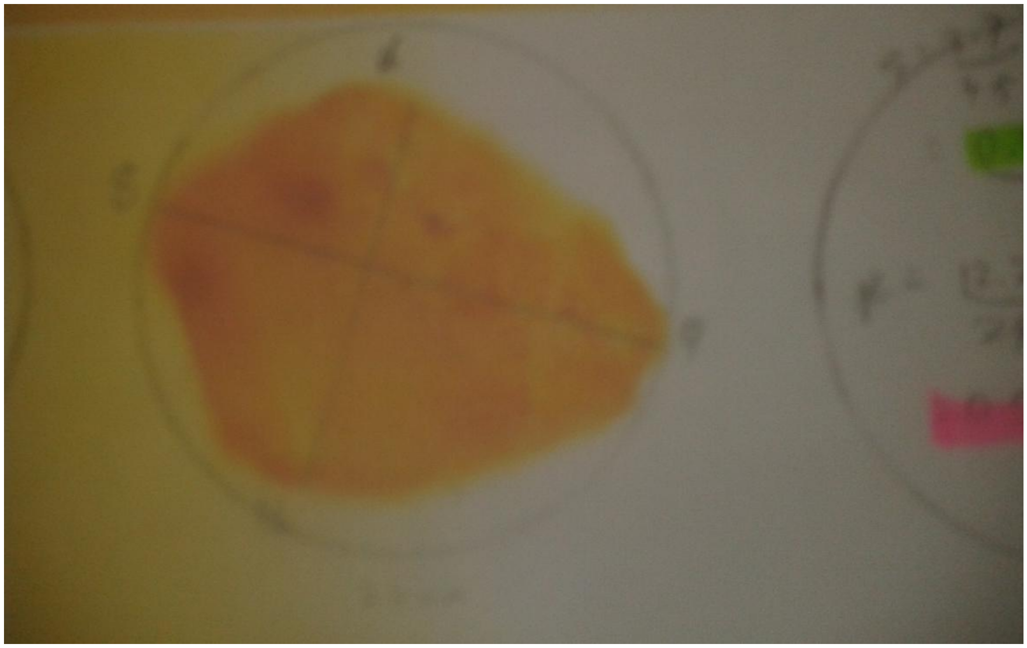


Figure 7 : Example Calculation for the maximum inscribed circle of a sand grain

After the full result obtained on the entire sample, the data are statistically expressed as a roundness and sphericity distribution by plotting cumulative percentage plot and roundness/sphericity histogram. From, the plot, the author is able to calculate the mean sphericity and roundness of the sample. This is to get the representative value of roundness and sphericity of the samples. The mean value is preferred because it is more commonly used rather than median value (Krumbein & Sloss, Stratigraphy and Sedimentation, 1963).

Permeability Test

For the permeability test, the experiment that been used is the Constant Head method (Civil Engineering Department, Universiti Teknologi PETRONAS, 2013). This test aims to obtain the value of hydraulic permeability, k, of the sand pack for each sample. The sample chosen for this test are the same as being used in the previous test which consist of sample of interested size (20/40 Mesh Size or 400 microns - 841 microns). The apparatus and procedures for this test are as follow;

Apparatus

1) A permeameter
2) A vertical adjustable reservoir tank
3) A set of manometer tubes, all of the same internal diameter
4) A pinch cock on the flexible adjacent to each gland.
5) Filter material of a suitable grading for placing adjacent to the perforated plates at each end of the permeameter
6) Measuring cylinders, 1000mL
7) A stop watch readable to 1s
8) A balance readable 1g

Procedures: Initial Preparations

1) The internal diameter of the permeability cell is measured at several places and the average diameter is recorded to the nearest 1mm
2) The distance between each manometer gland and the text along the same vertical line is measured to the nearest 1mm
3) The apparatus is assembled (refer Figure 11)
4) The length of the sample is measured and the average measurement is recorded.
5) The control valve is closed.
6) The inlet reservoir is set at a level a little above the top of permeameter cell and the valve is opened. The manometer tube pinch cock is opened one by one and no air is ensure to be trapped in the flexible tubing as the water flows into the manometer tubes. The water in all the tubes shall reach the level of reservoir surface. The permeameter is now ready for test under the normal conditions of downward flow.

Procedures: Downward flow of water through the sample

1) The height of the inlet reservoir is adjusted to a suitable level with regard to the hydraulic gradient to be imposed on the sample.
2) Fully open the control valve at the base to produce flow through the sample under a hydraulic gradient appreciable less than unity. The water levels in the

manometer tubes are allowed to become stable before starting the test measurements.

3) A measuring cylinder is placed under the outlet form the discharge reservoir and the timer is started simultaneously.
4) The time required to collect a 1000mL of water is recorded.
5) The levels of water in the manometer tubes are recorded.
6) The temperature of water in the water discharge reservoir is recorded.
7) The step 2 to 6 is repeated for another flow; half-open and slightly opened valve.

Calculations and Plotting

1) Rate of flow, q

   $q = Q/t$

   where; Q = volume of water collected

   t = time period required to collect 1000mL of water

2) Hydraulic Gradient, i

   i = h/y

   where; h = the difference between the two manometer levels (mm)

   y = the difference between the corresponding gland points (mm)

3) Hydraulic Permeability, k (m/s)

$$k = \frac{q}{i}\frac{Rt}{A}$$

Where; A = area of cross section of the sample (mm^2)

Rt = the temperature correction factor for the viscosity of water derived from Figure 8 , to standardize the permeability to 20 ^{o}C.

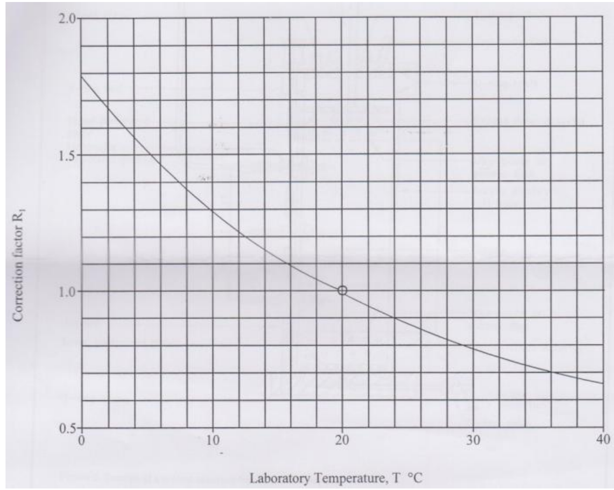


Figure 8 : Temperature correction curve for coefficients of consolidation and permeability

4) Plotting the graph of rate of flow, q versus hydraulic gradient, i and determine the slope which is q/i.

3.3 Key Milestone

Below are the key milestones that need to be achieved by the author throughout the period of the research.

FYP 1	FYP 2
• Project Topic Selected (30th Jan 2013, Week 3) • Preliminirary Research work done (15th Feb 2013, Week 5) • Extended Proposal Submitted (27th Feb 2013, Week 7) • Proposal Defence are carried out (13th Mar 2013, Week 9) • Tested methodology and Preliminirary Result (5th Apr 2013, Week 12) • Interim Draft Report Submitted and Discussed (12th Apr 2013, Week 13)	• Data and Sample Fully Gathered (21st Jun 2013, Week 6) • Progress Report Submitted (28th Jun 2013, Week 7) • Result Obtained (12th Jul 2013, Week 9) • Pre-Sedex (19th Jul 2013, Week 10) • Draft Report Submitted (26th Jul 2013, Week 11) • Dissertation (soft bound) Submitted (2nd Aug 2013, Week 12) • Technical Paper Submitted

• Interim Report Submitted (19th Apr 2013, Week 14)	(2nd Aug 2013, Week 12) • Oral Presentation Conducted (9th Aug 2013, Week 13) • Project Dissertation (hard bound) Submitted (23rd Aug 2013, Week 15)

Table 2 : Key Milestone

3.4 Gantt Chart

The key milestones explained earlier are summarized in the Gantt chart in the **Appendix I.**

3.5 Tools and Equipment

The basis of this project is mainly researching and developing theory. In the early part of the research, mostly the author will download technical papers and journal from subscribed online database for research purpose. Only in the later stage, the author will start conducting experiment using the following equipment.

Figure 9 : Sieve Shaker

Figure 11 : Meiji Polarizing Microscope attached with camera

Figure 10 : Constant Head experimental setup

CHAPTER 4: RESULT & DISCUSSION

The results are arranged based on type of experiment done and then further arranged based on each specific location. In order to describe the sand, the "Wentworth Article Size Classification for Sand" is used. It uses a geometric interval of ½ to define the limits of each size fraction (Spalding, Duncan, & Norcross Nu'u, 2009).

Category	Type	Size (mm)
Boulders	Boulders	250–100
Gravel	Cobbles	65–250
	Pebbles	4–65
	Granules	2–4
Sand	Very coarse sand	1–2
	Coarse sand	0.5–1
	Medium sand	0.25–0.5
	Fine sand	0.125–0.25
	Very fine sand	0.0625–0.125
Mud	Coarse silt	0.031–0.625
	Medium silt	0.156–0.031
	Fine silt	0.0078–0.156
	Very fine silt	0.0039–0.0078
	Clay	< 0.0039
	Dust	< 0.0005

Table 3 : Wentworth Article Size Classification for Sand

For the soil gradation, a well-graded soil consists of a wide range of sizes and has a good representation of all sizes. While, poorly graded soil is a soil that does not have a good representation of all particles sizes. Poorly graded soil can be divided into two sub-categories which are uniformly graded and gap-graded soil. A uniformly graded soil has most of its particles at about the same size. On the other hand, gap-graded soil is a soil that has an extra or lack of certain particle sizes. (Integrated Publishing, 2009).

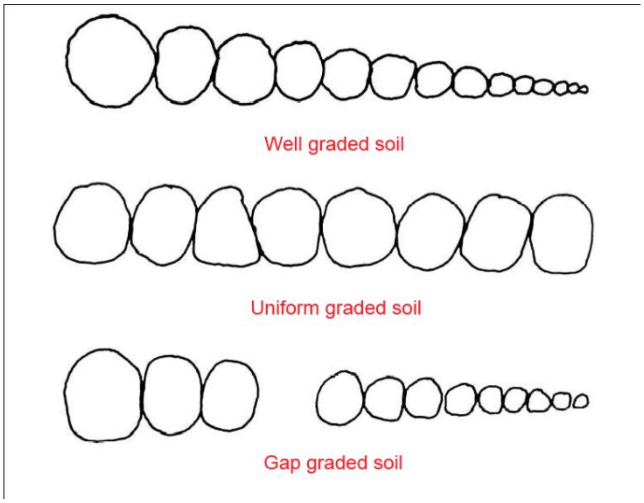


Figure 12 : Soil Gradation

4.1 Particle Distribution Size (Sieving Analysis)

LOCATION 1: CHERATING

L1S1

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.1	360.8	6.7	1.21
0.6	403.9	420.45	16.55	2.98
0.425	305	329.1	24.1	4.35
0.3	354.6	452.1	97.5	17.58
0.212	275.3	472.8	197.5	35.61
0.15	268.7	427.7	159	28.67
0.063	264	311.5	47.5	8.56
Pan	386.4	392.2	5.8	1.05
Total			554.65	100.00

Table 4 : Sieve Analysis Result for sample L1S1

L1S2

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.6	366.8	12.2	1.95
0.6	404.5	405.6	1.1	0.18
0.425	305.5	369.9	64.4	10.28
0.3	355.5	393.3	37.8	6.03
0.212	276	543.5	267.5	42.68
0.15	269.1	477.6	208.5	33.27
0.063	364.6	399.5	34.9	5.57
Pan	387.4	387.7	0.3	0.05
Total			626.7	100.00

Table 5 : Sieve Analysis Result for sample L1S2

L1S3

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	353.9	353.9	0	0.00
0.6	403.7	403.7	0	0.00
0.425	304.9	305.5	0.6	0.08
0.3	354.6	376.7	22.1	2.81
0.212	275.2	629.6	354.4	45.09
0.15	268.5	627.9	359.4	45.73
0.063	263.84	312.7	48.86	6.22
Pan	386.4	387	0.6	0.08
Total			785.96	100.00

Table 6 : Sieve Analysis Result for sample L1S3

L1S4

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	353.9	354.1	0.2	0.02
0.6	403.9	404.6	0.7	0.08
0.425	304.9	308.1	3.2	0.35
0.3	354.5	416.8	62.3	6.77
0.212	275.2	759.5	484.3	52.62
0.15	268.5	577.6	309.1	33.58
0.063	263.8	323.6	59.8	6.50
Pan	386.3	387.1	0.8	0.09
Total			920.4	100.00

Table 7 : Sieve Analysis Result for sample L1S4

L1S5

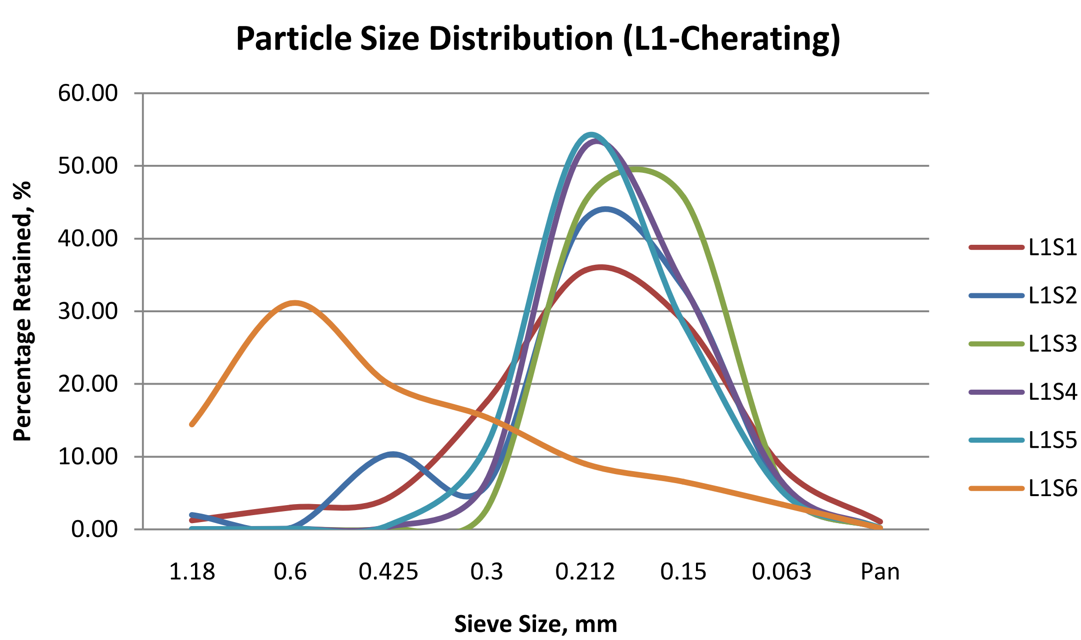
Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.1	354.4	0.3	0.04
0.6	403.9	404.5	0.6	0.08
0.425	305	309.2	4.2	0.54
0.3	354.6	444.9	90.3	11.58
0.212	275.3	696.7	421.4	54.03
0.15	268.7	489.5	220.8	28.31
0.063	264	304.9	40.9	5.24
Pan	386.4	387.9	1.5	0.19
Total			780	100.00

Table 8 : Sieve Analysis Result for sample L1S5

L1S6

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	353.9	466.7	112.8	14.40
0.6	403.9	647.5	243.6	31.10
0.425	305	461.8	156.8	20.02
0.3	354.5	474.9	120.4	15.37
0.212	275.2	345.8	70.6	9.01
0.15	268.5	319.6	51.1	6.52
0.063	263.8	290.6	26.8	3.42
Pan	386.4	387.7	1.3	0.17
Total			783.4	100.00

Table 9 : Sieve Analysis Result for sample L1S6



From the graph, we can observe that the sand sample taken from Cherating beach consists of mostly medium to fine sand and the sand are well graded. However, the sand sample L1S6 has a bit different distribution and size since it is taken quite far from the other sample. The sample L1S6 consists of mainly very coarse to medium sand. Hence, the sample is found to be not suitable for further testing since the size of overall sample is not in the range of interested size (20/40 Mesh Size or 400 microns - 841 microns).

LOCATION 2: RANTAU ABANG SOUTH

L2S1

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	353.9	354	0.1	0.01
0.6	403.9	408.6	4.7	0.68
0.425	305	325.4	20.4	2.94
0.3	354.6	607.1	252.5	36.41
0.212	275.3	615.3	340	49.03
0.15	268.5	315.8	47.3	6.82
0.063	236.2	264	27.8	4.01
Pan	386.4	387.1	0.7	0.10
Total			693.5	100.00

Table 10 : Sieve Analysis Result for sample L2S1

L2S2

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	353.7	353.9	0.2	0.02
0.6	403.9	405.6	1.7	0.21
0.425	305	348.9	43.9	5.32
0.3	354.5	668.2	313.7	38.04
0.212	275.2	680.5	405.3	49.15
0.15	268.6	325.8	57.2	6.94
0.063	263.8	265.9	2.1	0.25
Pan	386.4	386.9	0.5	0.06
Total			824.6	100.00

Table 11 : Sieve Analysis Result for sample L2S2

L2S3

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.6	354.7	0.1	0.01
0.6	404.6	406.2	1.6	0.18
0.425	305.5	339	33.5	3.70
0.3	355.4	733.7	378.3	41.80
0.212	275.8	714	438.2	48.42
0.15	269	318.6	49.6	5.48
0.063	264.6	267.3	2.7	0.30
Pan	387.5	388.5	1	0.11
Total			905	100.00

Table 12 : Sieve Analysis Result for sample L2S3

L2S4

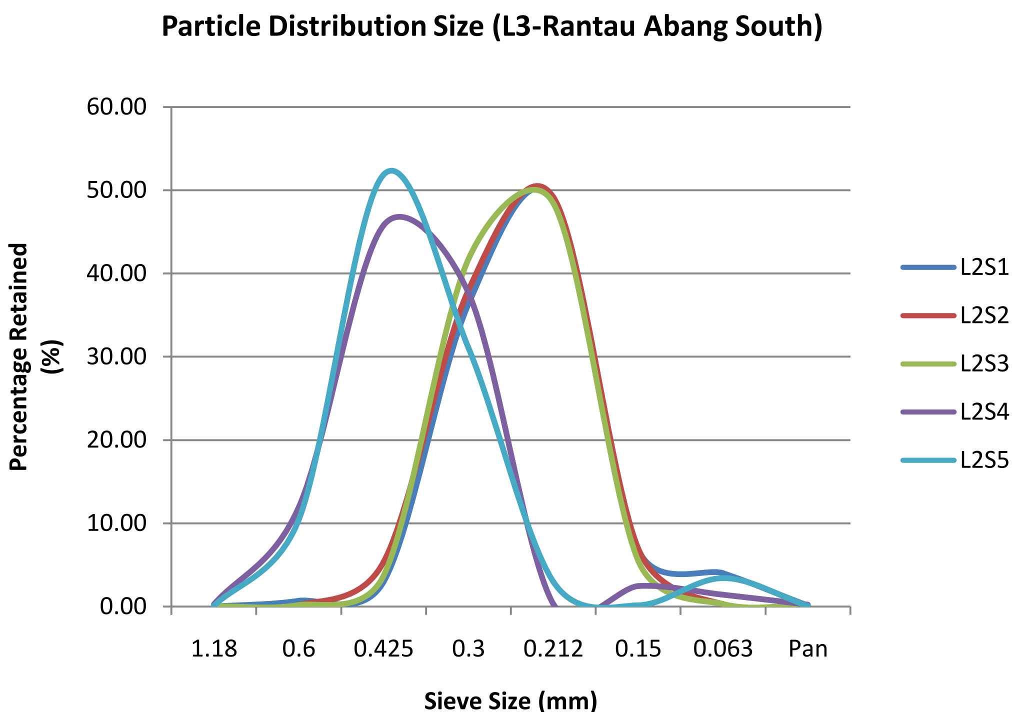
Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	353.7	355.6	1.9	0.26
0.6	403.9	492.4	88.5	11.93
0.425	305	644.7	339.7	45.79
0.3	354.5	633.7	279.2	37.64
0.212	275.2	277.3	2.1	0.28
0.15	268.6	286.8	18.2	2.45
0.063	263.8	274.3	10.5	1.42
Pan	386.4	388.1	1.7	0.23
Total			741.8	100.00

Table 13 : Sieve Analysis Result for sample L2S4

L2S5

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	353.9	354.5	0.6	0.07
0.6	403.9	488.8	84.9	10.43
0.425	305	727.3	422.3	51.87
0.3	354.6	607.1	252.5	31.01
0.212	275.3	299.5	24.2	2.97
0.15	268.5	269.7	1.2	0.15
0.063	236.2	264	27.8	3.41
Pan	386.4	387.1	0.7	0.09
Total			814.2	100.00

Table 14 : Sieve Analysis Result for sample L2S5



From the graph, we can observe that 3 of the sand samples taken from Rantau Abang South (L2S1, L2S2 and L2S3) consist of mostly medium to fine sand. However, the sand samples L2S4 and L2S5 have a bit different distribution and size since it is taken quite far (around 100m) from the other sample. These two samples consist of mainly very coarse to medium sand. In overall, the sand in Rantau Abang South is a well graded type of sand. Hence, the sample is found to be suitable for further testing since the size of overall sample is in the range of interested size (20/40 Mesh Size or 400 microns - 841 microns).

LOCATION 3: RANTAU ABANG NORTH

L3S1

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.1	382	27.9	3.78
0.6	403.9	748.9	345	46.80
0.425	305	553.7	248.7	33.74
0.3	354.6	446.1	91.5	12.41
0.212	275.3	277.7	2.4	0.33
0.15	268.7	288.7	20	2.71
0.063	264	265.5	1.5	0.20
Pan	386.4	386.6	0.2	0.03
Total			737.2	100.00

Table 15 : Sieve Analysis Result for sample L3S1

L3S2

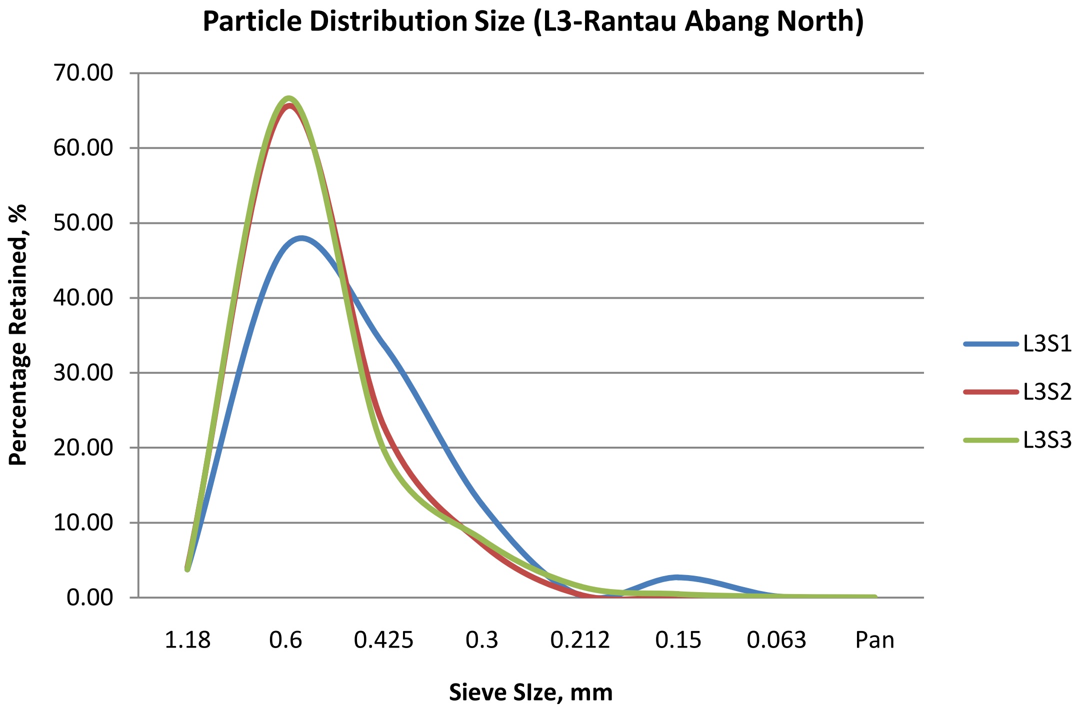
Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.1	392.9	38.8	4.04
0.6	403.9	1032	628.1	65.45
0.425	305	524.4	219.4	22.86
0.3	354.6	423.5	68.9	7.18
0.212	275.3	279.2	3.9	0.41
0.15	268.7	269	0.3	0.03
0.063	264	264.1	0.1	0.01
Pan	386.4	386.5	0.1	0.01
Total			959.6	100.00

Table 16 : Sieve Analysis Result for sample L3S2

L3S3

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.5	401.1	46.6	3.78
0.6	403.8	1224.6	820.8	66.50
0.425	305	548.4	243.4	19.72
0.3	354.5	450.8	96.3	7.80
0.212	275.3	293.7	18.4	1.49
0.15	265.7	271.8	6.1	0.49
0.063	264	265.7	1.7	0.14
Pan	386.4	387.3	0.9	0.07
Total			1234.2	100.00

Table 17 : Sieve Analysis Result for sample L3S3



From the graph, we can observe that the sand samples taken from Rantau Abang North consist of mostly very coarse to medium sand. In terms of its gradation, we can say that it is well graded sand. Hence, the sample is found to be suitable for further testing since the size of overall sample is in the range of interested size (20/40 Mesh Size or 400 microns - 841 microns).

LOCATION 4: MARANG

L4S1

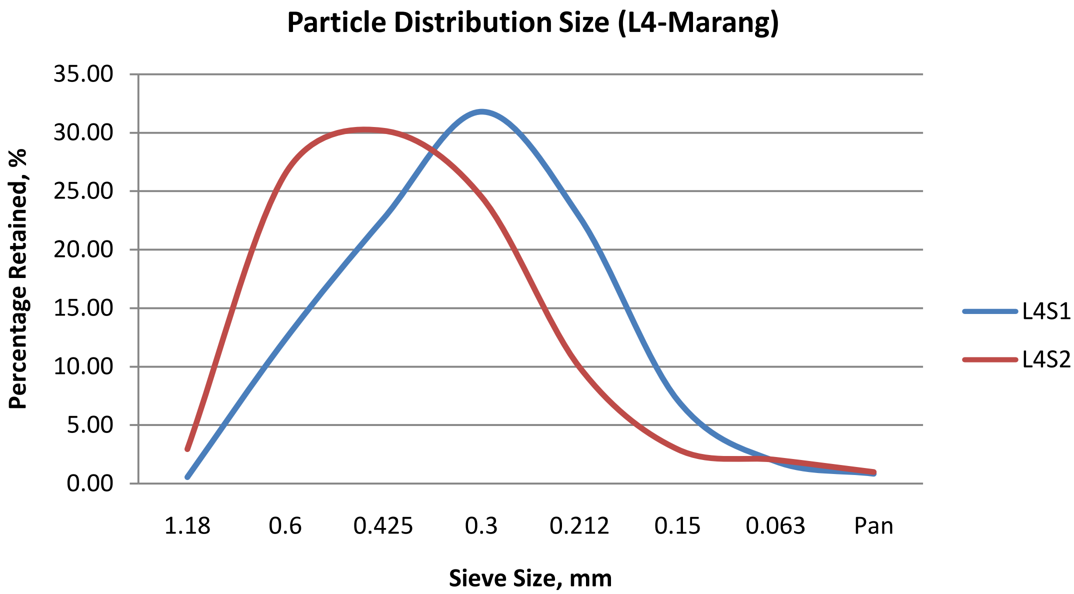
Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.5	357.9	3.4	0.55
0.6	403.8	480.7	76.9	12.35
0.425	305	446.1	141.1	22.65
0.3	354	552.1	198.1	31.80
0.212	275.3	417.3	142	22.80
0.15	268.6	313	44.4	7.13
0.063	263.9	275.7	11.8	1.89
Pan	386.5	391.7	5.2	0.83
Total			622.9	100.00

Table 18 : Sieve Analysis Result for sample L4S1

L4S2

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.1	387.4	33.3	2.94
0.6	403.9	703.5	299.6	26.49
0.425	305	646	341	30.15
0.3	354.6	631.8	277.2	24.51
0.212	275.3	387.7	112.4	9.94
0.15	268.7	301.9	33.2	2.94
0.063	264	287	23	2.03
Pan	386.4	397.6	11.2	0.99
Total			1130.9	100.00

Table 19 : Sieve Analysis Result for sample L4S2



From the graph, we can observe that the sand samples taken from Marang consist of a wide range of particle size which varies from very coarse to fine sand. In terms of its gradation, we can say that it is well graded sand. Hence, the sample is found to be suitable for further testing since the size of overall sample is in the range of interested size (20/40 Mesh Size or 400 microns - 841 microns).

LOCATION 5: RANTAU ABANG

L5S1

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	353.9	384.5	30.6	3.45
0.6	403.7	1059.8	656.1	73.99
0.425	304.8	461.3	156.5	17.65
0.3	354.4	391	36.6	4.13
0.212	275.1	280.4	5.3	0.60
0.15	268.5	269.5	1	0.11
0.063	263.8	264.2	0.4	0.05
Pan	386.2	386.4	0.2	0.02
Total			886.7	100.00

Table 20 : Sieve Analysis Result for sample L5S1

L5S2

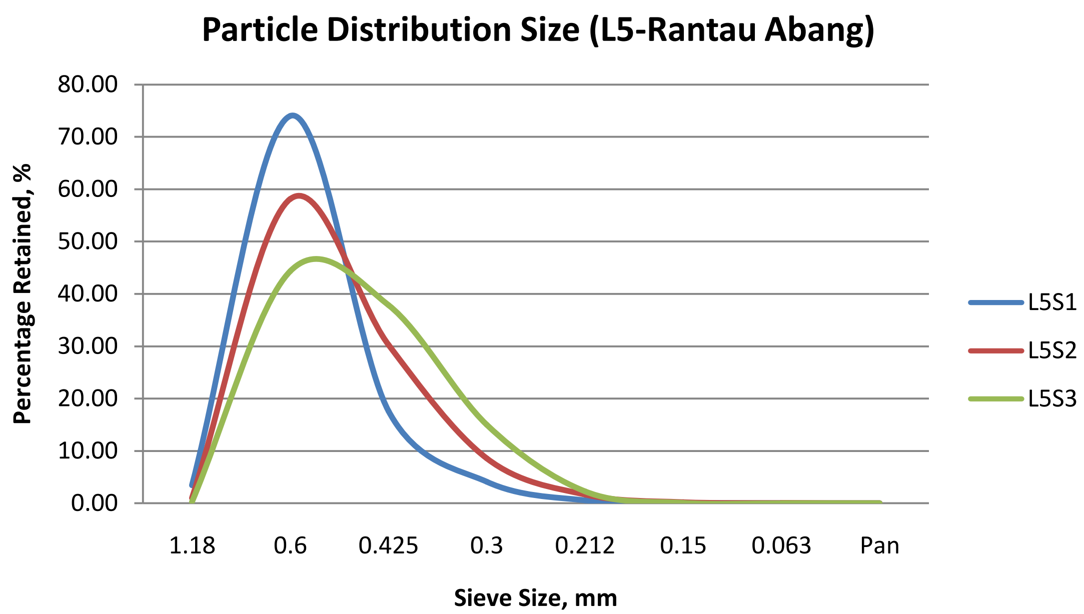
Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	354.7	362.9	8.2	1.00
0.6	404.5	880.2	475.7	58.14
0.425	305.6	553.2	247.6	30.26
0.3	355.4	425.8	70.4	8.60
0.212	275.9	289.6	13.7	1.67
0.15	269.1	271	1.9	0.23
0.063	264.5	265	0.5	0.06
Pan	387.4	387.6	0.2	0.02
Total			818.2	100.00

Table 21 : Sieve Analysis Result for sample L5S2

L5S3

Sieve (mm)	Weight of Sieve (g)	Weigh Sieve + Retained (g)	Retained (g)	Percentage (%)
1.18	353.8	355.9	2.1	0.28
0.6	387.3	716.9	329.6	44.36
0.425	304.9	586.5	281.6	37.90
0.3	354.7	466.4	111.7	15.03
0.212	275.4	292.4	17	2.29
0.15	268.6	269.4	0.8	0.11
0.063	263.8	263.9	0.1	0.01
Pan	386.4	386.5	0.1	0.01
Total			743	100.00

Table 22 : Sieve Analysis Result for sample L5S3



From the graph, we can observe that the sand samples taken from Rantau Abang consist mostly coarse to medium sand. In terms of its gradation, we can say that it is well graded sand. In overall, the properties of the sand from each sample are quite the same since they are taken at approximately close distance from each other. Hence, the sample is found to be suitable for further testing since the size of overall sample is in the range of interested size (20/40 Mesh Size or 400 microns - 841 microns).

4.2 Sphericity of Sand Particle

The manual hand calculation for the sphericity is attached in Appendix IV. A three batch of sample were chosen for this test which fall under the size range 20/40 Mesh Size or 400 microns - 841 microns. The samples are the sand that retain in 600micron, 425 micron, and 300micron sieve size. These three sizes are used based on the availability of the sieve size that fall under the range. The magnification of the microscope used to view the sample are as follow; 600micron (40x magnification), 425 micron (40x magnification), and 300 micron (100x magnification).

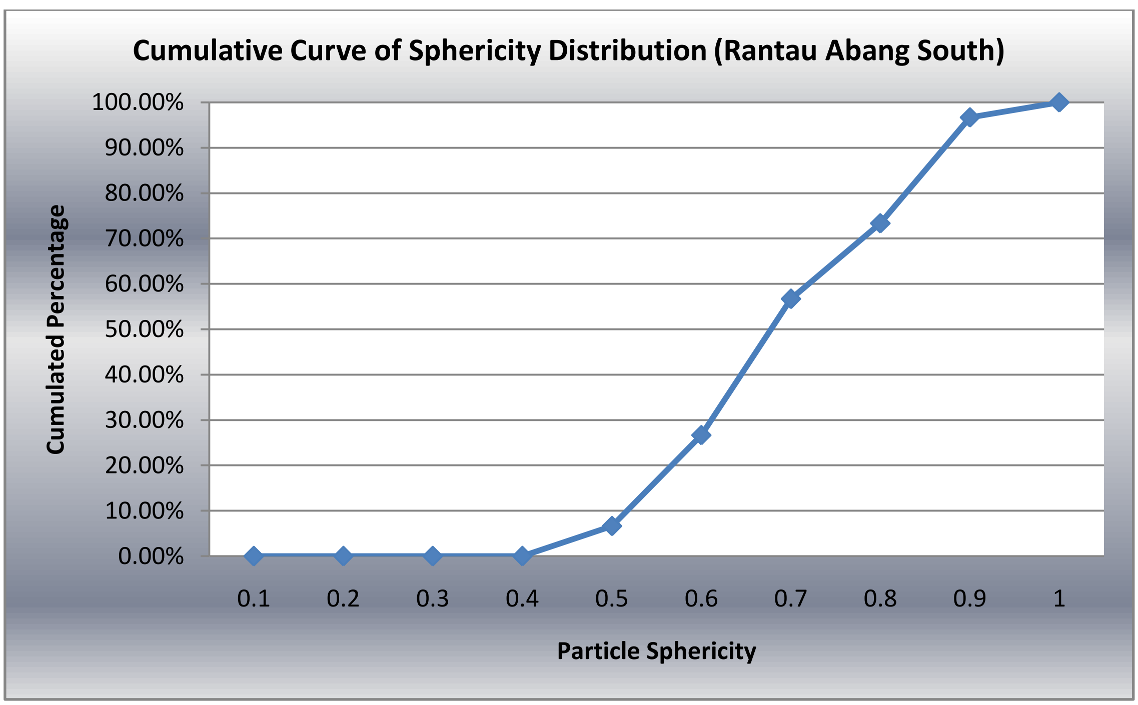
Location 2: Rantau Abang South

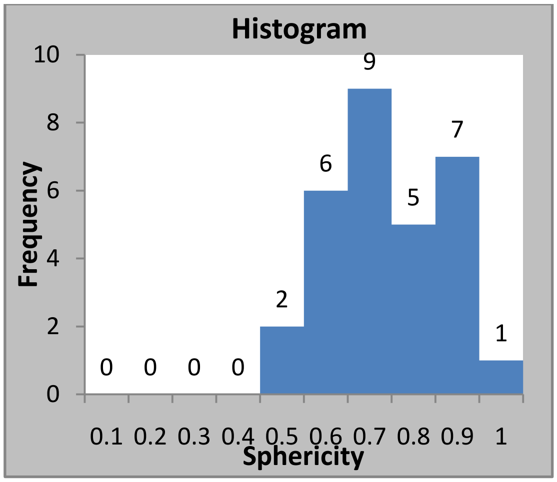
The following show the results of sphericity of all the sand grains (30 grains) for sample from Rantau Abang South.

0.57	0.59	0.84	0.8	0.79	0.7
0.85	0.63	0.87	0.8	0.7	0.41
0.93	0.59	0.63	0.67	0.63	0.82
0.58	0.44	0.67	0.7	0.56	0.77
0.87	0.77	0.54	0.89	0.63	0.82

Table 23 : Result of sphericity for Rantau Abang South

The sphericity data may be expressed as a sphericity distribution. The following are the cumulative percentage plot and sphericity histogram for Rantau Abang South's sample.



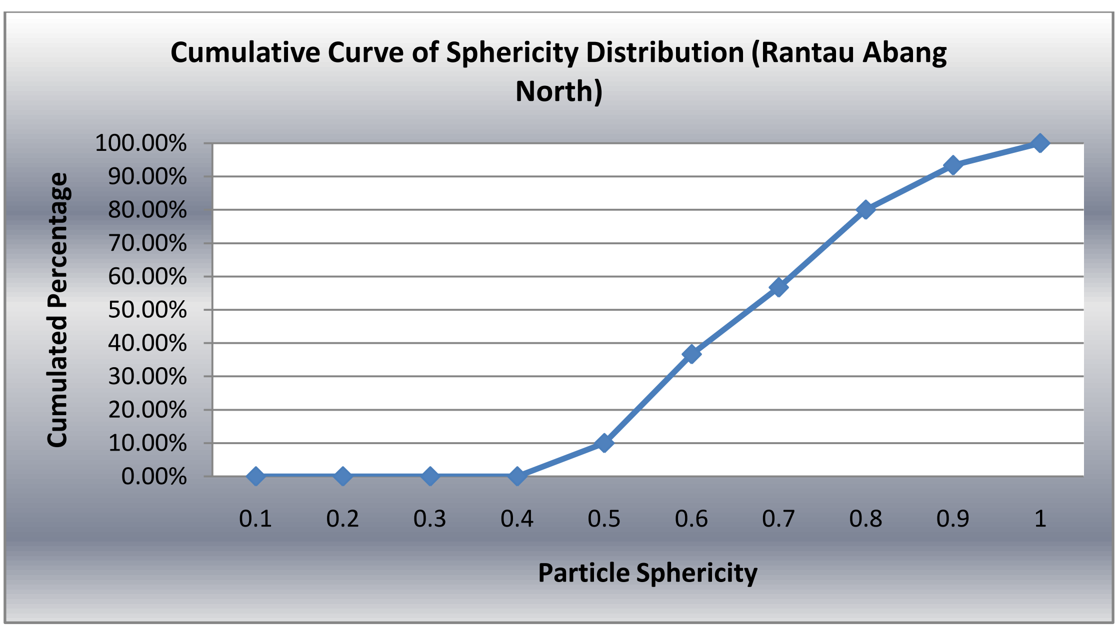


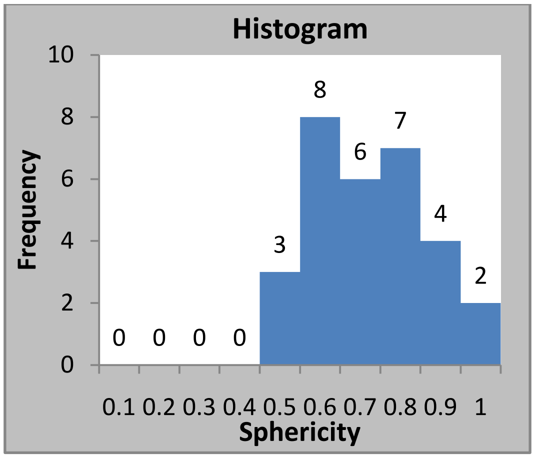
Class Midpoint, *m*	Frequency, *f*	*fm*
0.45	2	0.9
0.55	6	3.3
0.65	9	5.85
0.75	5	3.75
0.85	7	5.95
0.95	1	0.95
Total	30	20.7
Mean Sphericity	**=**	**0.69**

Location 2 : Rantau Abang North

0.62	0.57	0.51	0.53	0.51	0.47
0.97	0.83	0.74	0.79	0.54	0.77
0.57	0.44	0.58	0.89	0.8	0.89
0.69	0.77	0.44	0.83	0.54	0.68
0.69	0.77	0.69	0.91	0.68	0.74

Table 24 : Result of sphericity for Rantau Abang North



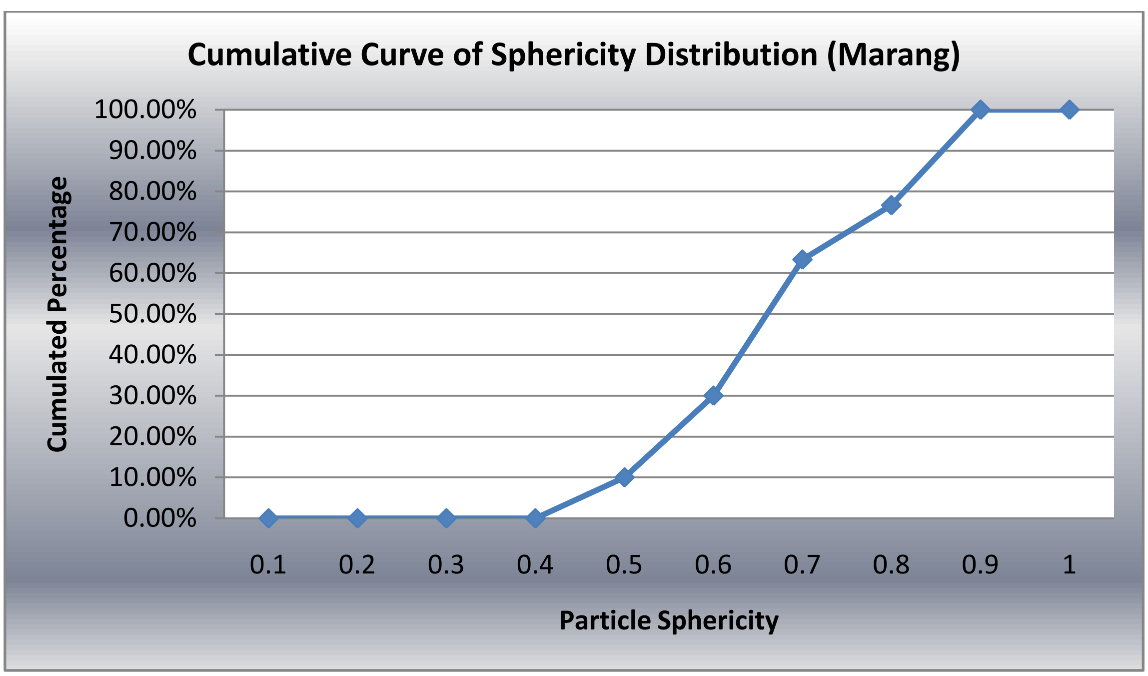


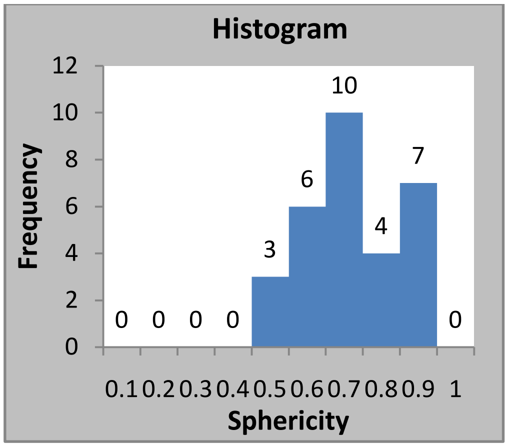
Class Midpoint, *m*	Frequency, *f*	*fm*
0.45	3	1.35
0.55	8	4.4
0.65	6	3.9
0.75	7	5.25
0.85	4	3.4
0.95	2	1.9
Total	30	20.2
Mean Sphericity	**=**	**0.67**

<u>Location 4 : Marang</u>

0.84	0.63	0.68	0.65	0.77	0.53
0.42	0.64	0.44	0.73	0.68	0.6
0.66	0.62	0.66	0.61	0.58	0.81
0.75	0.42	0.56	0.81	0.58	0.6
0.68	0.88	0.74	0.82	0.82	0.87

Table 25 : Result of sphericity for Marang



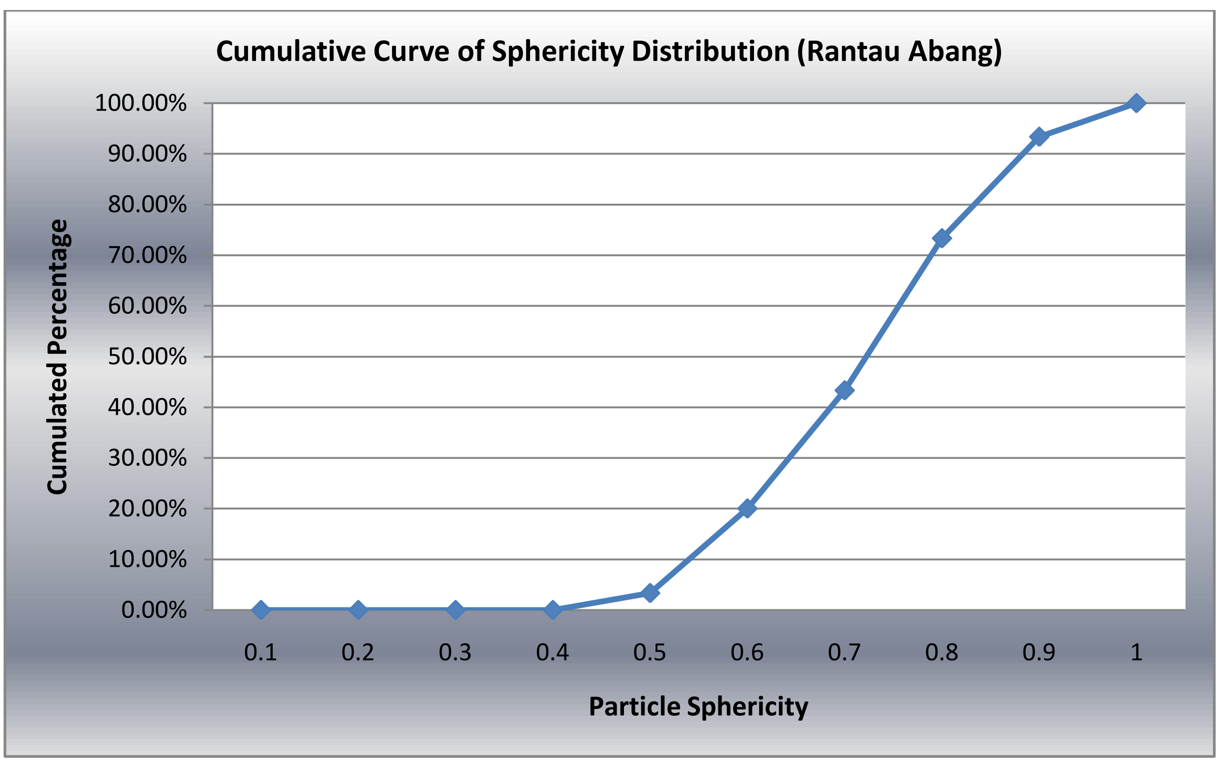


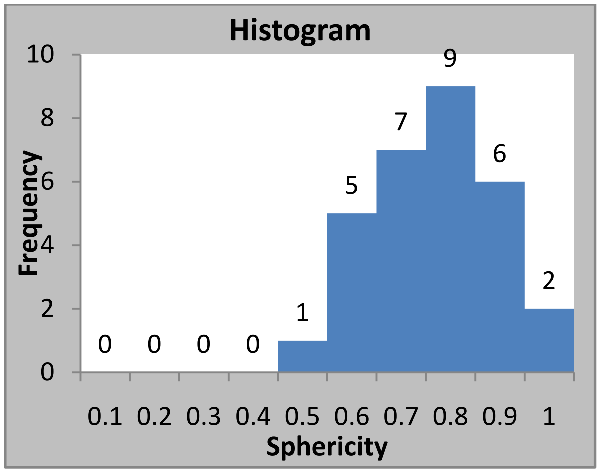
Class Midpoint, *m*	Frequency, *f*	*fm*
0.45	3	1.35
0.55	6	3.3
0.65	10	6.5
0.75	4	3
0.85	7	5.95
Total	30	20.1
Mean Sphericity	**=**	**0.67**

Location 5: Rantau Abang

0.7	0.84	0.78	0.61	0.59	0.93
0.63	0.73	0.71	0.68	0.58	0.69
0.73	0.79	0.96	0.85	0.47	0.67
0.73	0.78	0.87	0.71	0.56	0.87
0.83	0.6	0.58	0.85	0.73	0.62

Table 26 : Result of sphericity for Rantau Abang





Class Midpoint, *m*	Frequency, *f*	*fm*
0.45	1	0.45
0.55	5	2.75
0.65	7	4.55
0.75	9	6.75
0.85	6	5.1
0.95	2	1.9
Total	30	21.5
Mean Sphericity	**=**	**0.72**

4.3 Roundness of Sand Particle

The manual hand calculations for the roundness are attached in Appendix IV. A three batch of sample were chosen for this test which fall under the size range 20/40 Mesh Size or 400 microns - 841 microns. The samples are the sand that retain in 600micron, 425 micron, and 300micron sieve size. These three sizes are used based on the availability of the sieve size that fall under the range. The magnification of the microscope used to view the sample are as follow; 600micron (40x magnification), 425 micron (40x magnification), and 300 micron (100x magnification).

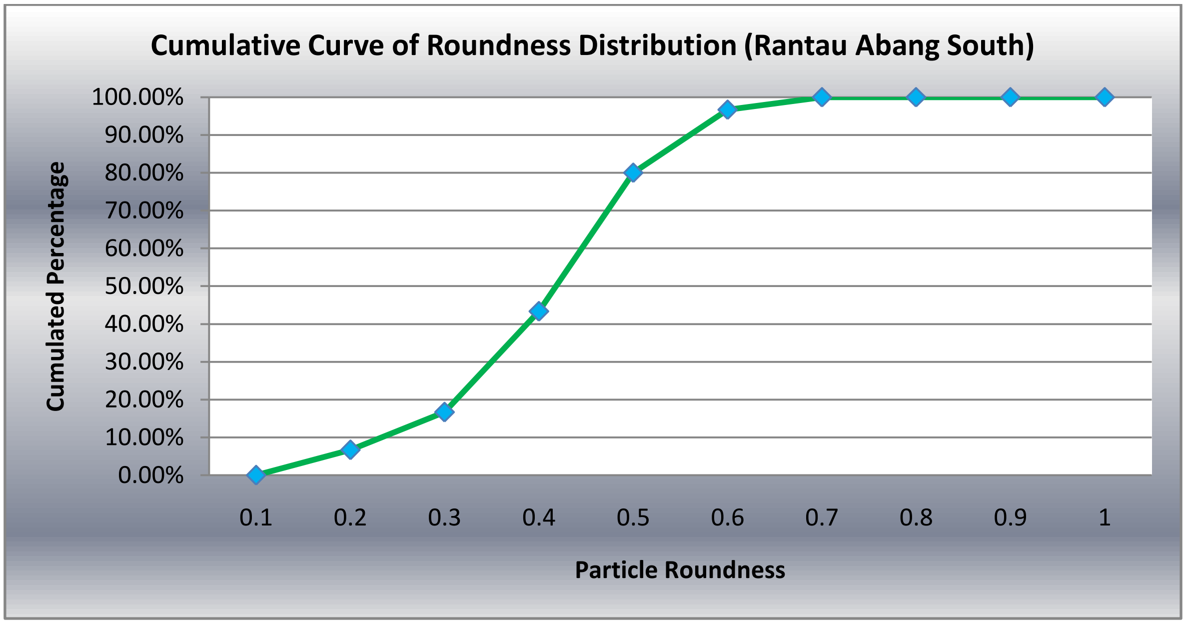
<u>Location 2 : Rantau Abang South</u>

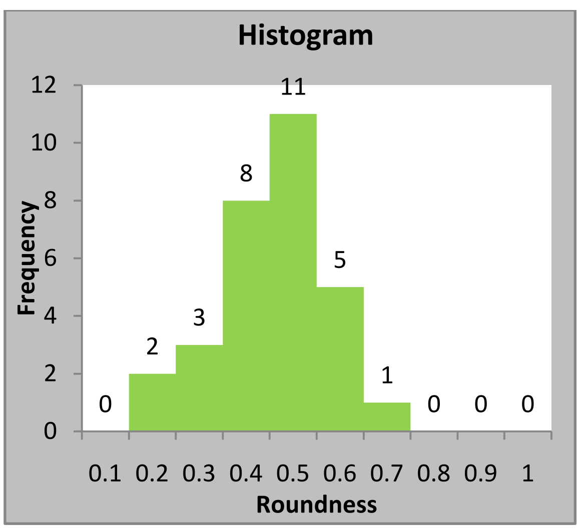
The following show the results of roundness of all the sand grains (30 grains) for sample from Rantau Abang South.

0.4	0.16	0.55	0.46	0.41	0.34
0.39	0.33	0.63	0.45	0.41	0.43
0.58	0.47	0.42	0.29	0.42	0.47
0.33	0.21	0.42	0.4	0.3	0.6
0.57	0.48	0.39	0.37	0.18	0.51

Table 27 : Result of roundness for Rantau Abang South

The following are the cumulative percentage plot and roundness histogram for Rantau Abang South's sample.



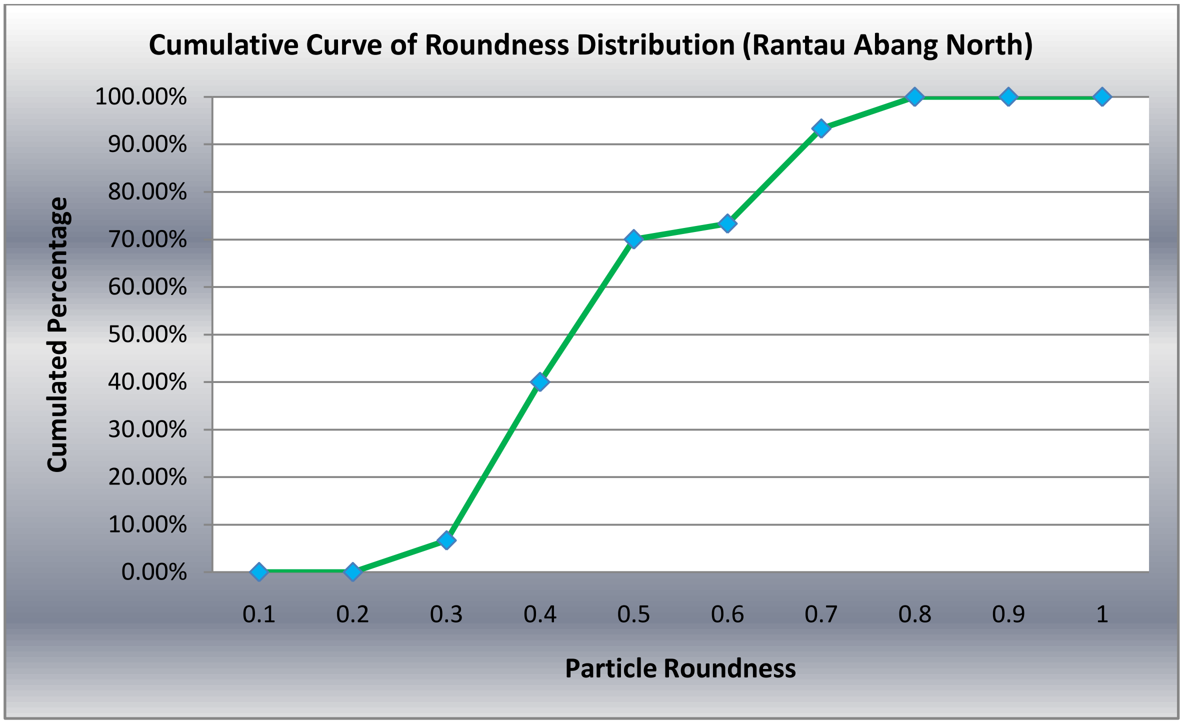


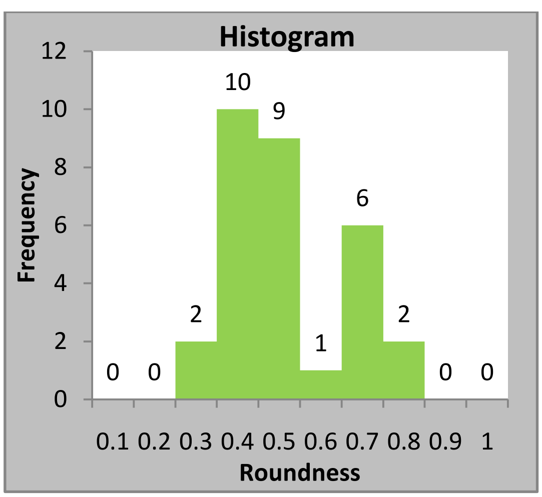
Class Midpoint, *m*	Frequency, *f*	*fm*
0.15	2	0.3
0.25	3	0.75
0.35	8	2.8
0.45	11	4.95
0.55	5	2.75
0.65	1	0.65
Total	30	12.2
Mean Roundness	**=**	**0.41**

Location 3: Rantau Abang North

0.43	0.39	0.46	0.42	0.42	0.4
0.47	0.55	0.48	0.43	0.33	0.7
0.4	0.36	0.3	0.63	0.73	0.5
0.61	0.45	0.24	0.78	0.34	0.38
0.35	0.37	0.61	0.61	0.61	0.34

Table 28 : Result of roundness for Rantau Abang North



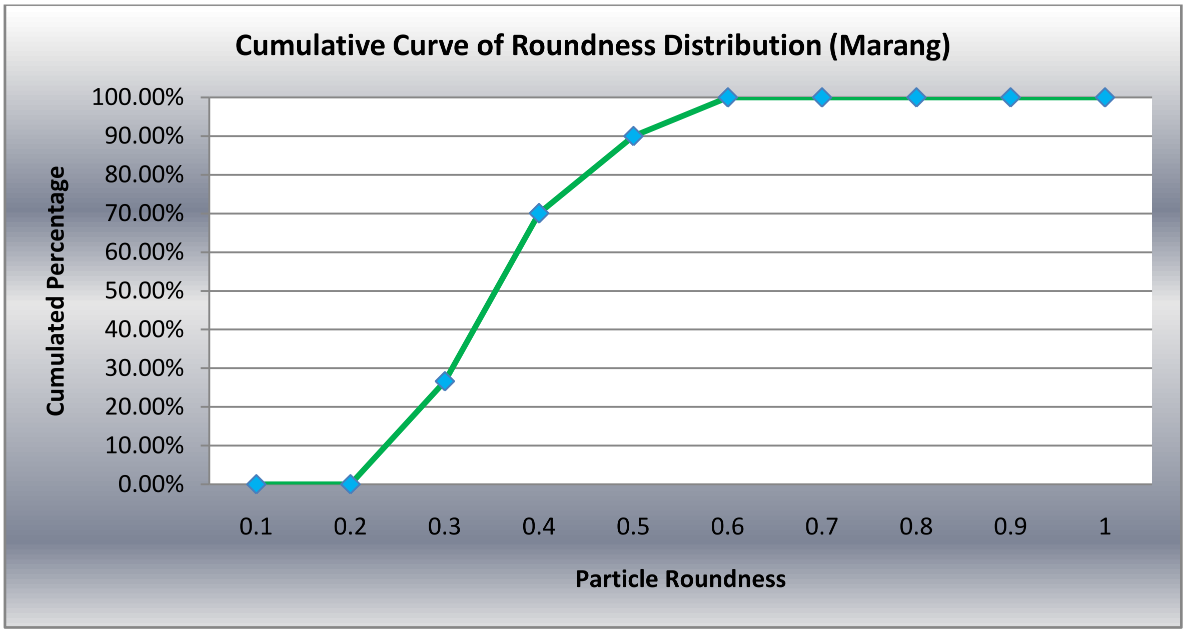


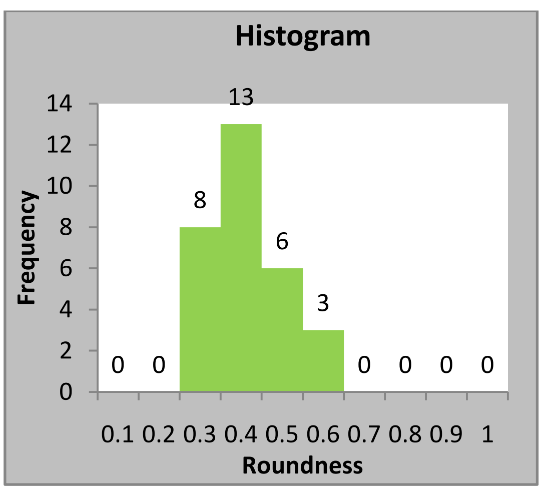
Class Midpoint, *m*	Frequency, *f*	*fm*
0.25	2	0.5
0.35	10	3.5
0.45	9	4.05
0.55	1	0.55
0.65	6	3.9
0.75	2	1.5
Total	30	14
Mean Roundness	**=**	**0.47**

Location 4 : Marang

0.32	0.39	0.29	0.42	0.44	0.34
0.23	0.3	0.28	0.29	0.54	0.34
0.42	0.37	0.31	0.33	0.39	0.58
0.33	0.33	0.29	0.5	0.28	0.57
0.34	0.41	0.46	0.22	0.37	0.38

Table 29 : Result of roundness for Marang



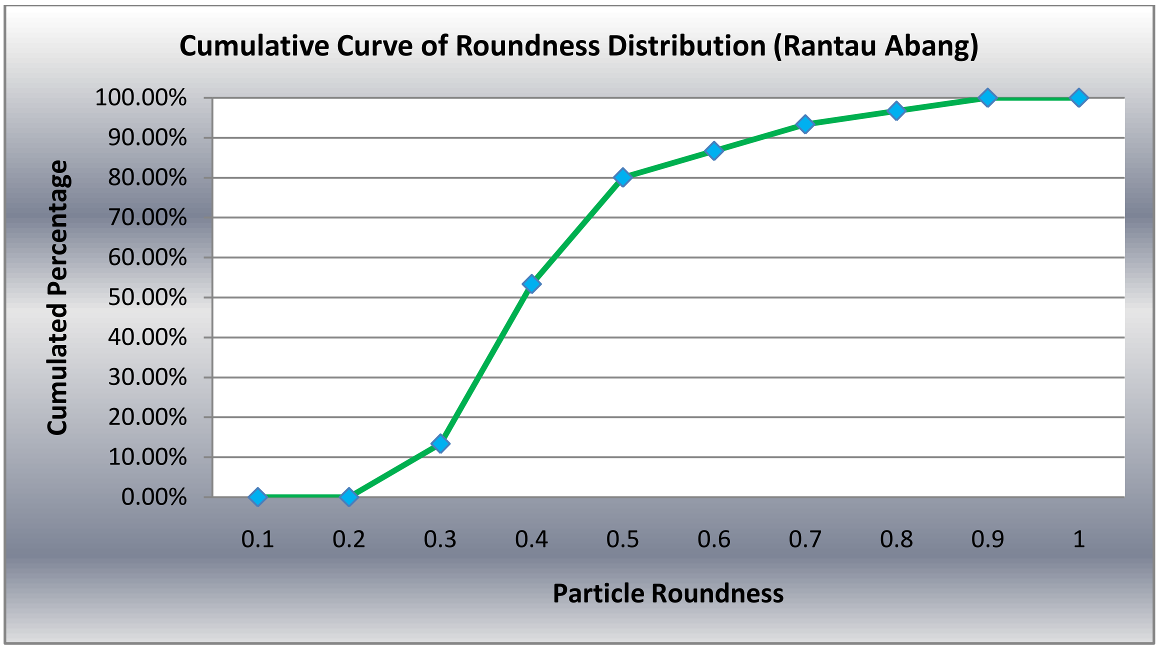


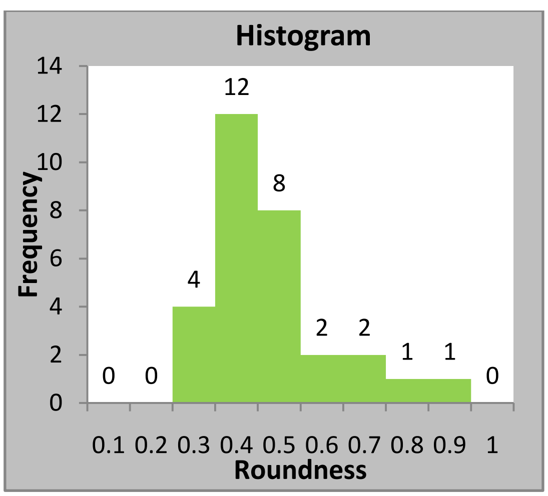
Class Midpoint, *m*	Frequency, *f*	*fm*
0.25	8	2
0.35	13	4.55
0.45	6	2.7
0.55	3	1.65
Total	30	10.9
Mean Roundness	**=**	**0.36**

Location 5 : Rantau Abang

0.46	0.83	0.48	0.39	0.3	0.71
0.42	0.7	0.34	0.24	0.36	0.39
0.28	0.57	0.39	0.3	0.31	0.37
0.5	0.52	0.48	0.44	0.4	0.38
0.45	0.46	0.33	0.34	0.7	0.33

Table 30 : Result of roundness for Marang





Class Midpoint, *m*	Frequency, *f*	*fm*
0.25	4	1
0.35	12	4.2
0.45	8	3.6
0.55	2	1.1
0.65	2	1.3
0.75	1	0.75
0.85	1	0.85
Total	30	12.8
Mean Roundness	**=**	**0.43**

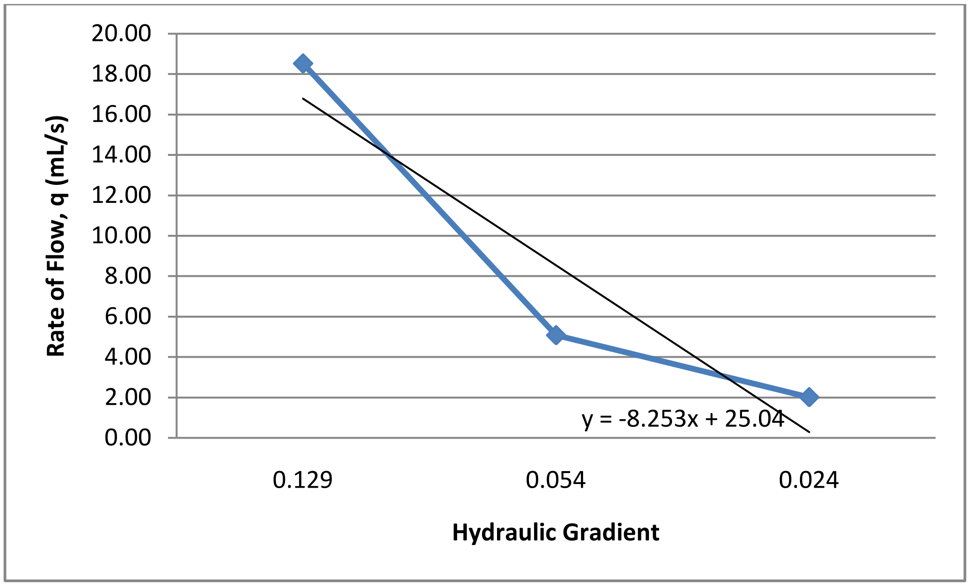
4.4 Hydraulic Permeability

The experiments to obtain the hydraulic permeability of the samples are run three times each with different flow; fully opened, half-opened and slightly open valve. The purpose of these three different flows is to obtained different hydraulic gradient for the experiments. The value of hydraulic permeability is calculated by first plotting graph of flow rate, q versus hydraulic gradient, i and then by using the equation. The hydraulic permeability, k obtained is in the unit of m/s. To convert it to Darcy unit, the following conversion factor is used.

$$1 \text{ Darcy, D} = 0.831 \text{ m/s (at } 20\ ^{o}\text{C)}$$

<u>Location 2: Rantau Abang South</u>

Test Method : BS1377 : Part 2 : 1990				
Sample Diameter, mm	75			
Sample Length, mm	88			
Area, mm^2	4417.9			
Volume, cm^3	388.8			
Type of Flow		Fully Opened	Half Opened	Slightly Opened
Measure Flow, Q	mL	1000	1000	1000
Rate of Flow, q	mL/s	18.52	5.08	2.01
Height, h	m	0.018	0.0075	0.0033
Hydraulic Gradient, i=h/y		0.129	0.054	0.024
Temperature, T	T (°C)	23	23	23
	Rt	0.95	0.95	0.95
Velocity, v = q/A	m/s	0.0042	0.0011	0.0005
Type of Flow	Manometer Level (cm)			Time, t (s)
	H1	H2	rH	
Fully Opened	63	45	18	54
Half Opened	91.5	84	7.5	197
Slightly Opened	93	89.7	3.3	497



To calculate hydraulic permeability from graph, by using the equations;

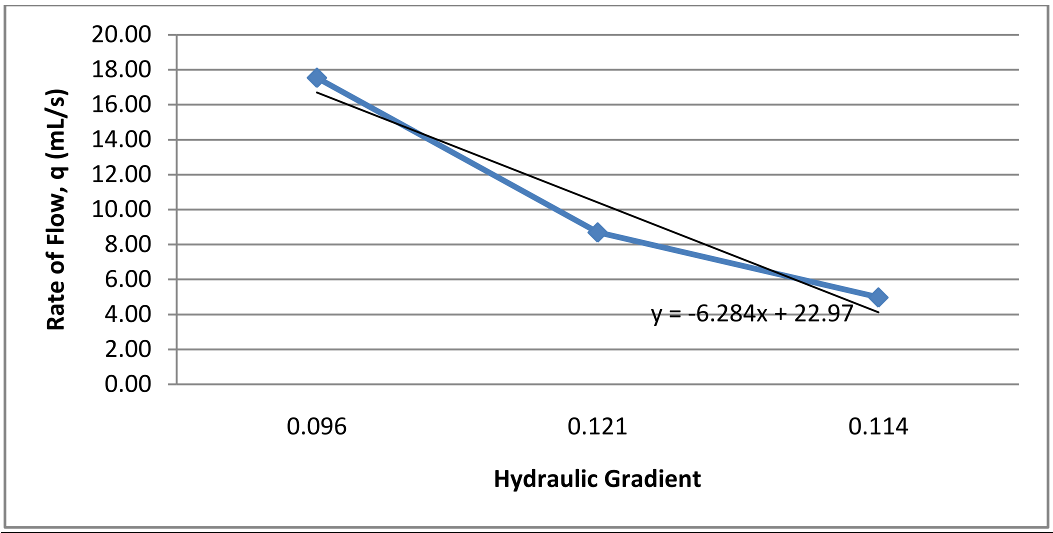
$$k = 1.7392 \times 10^{-3}\ m/s$$

$$\underline{k = 2.0929\ mD}$$

Location 3 : Rantau Abang North

Test Method : BS1377 : Part 2 : 1990				
Sample Diameter, mm	75			
Sample Length, mm	93			
Area, mm^2	4417.9			
Volume, cm^2	410.9			
Type of Flow		Fully Opened	Half Opened	Slightly Opened
Measure Flow, Q	mL	1000	1000	1000
Rate of Flow, q	mL/s	17.54	8.70	4.98
Height, h	m	0.0135	0.017	0.016
Hydraulic Gradient, i=h/y		0.096	0.121	0.114
Temperature, T	T (°C)	23	23	23
	Rt	0.95	0.95	0.95
Velocity, v = q/A	m/s	0.0040	0.0020	0.0011

Type of Flow	Manometer Level (cm)			Time, t (s)
	H1	H2	△H	
Fully Opened	67	53.5	13.5	57
Half Opened	81.5	64.5	17	115
Slightly Opened	94	78	16	201



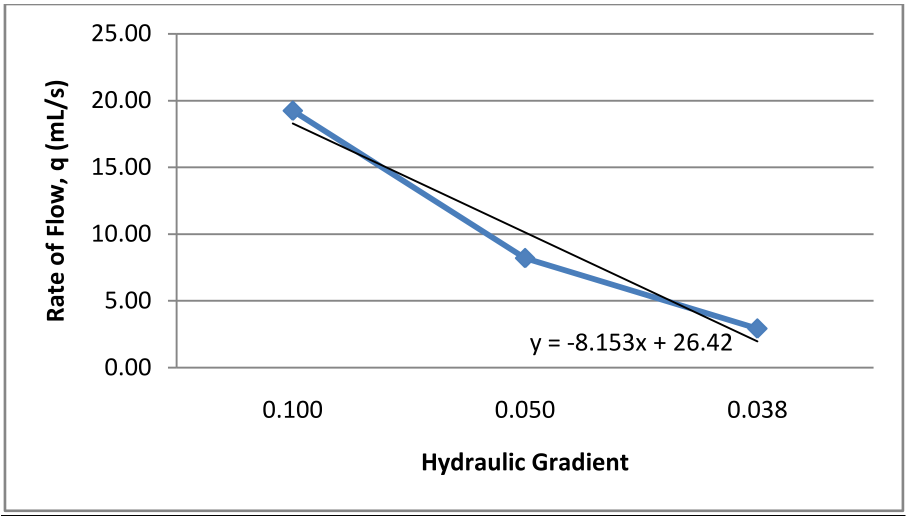
$$k = 1.3243 \times 10^{-3} \ m/s$$

$$\underline{k = 1.5936 \ mD}$$

Location 4: Marang

Test Method : BS1377 : Part 2 : 1990				
Sample Diameter, mm	75			
Sample Length, mm	75			
Area, mm^2	4417.9			
Volume, cm^2	331.38			
Type of Flow		Fully Opened	Half Opened	Slightly Opened
Measure Flow, Q	mL	1000	1000	1000
Rate of Flow, q	mL/s	19.23	8.20	2.92
Height, h	m	0.014	0.007	0.0053
Hydraulic Gradient, i=h/y		0.100	0.050	0.038
Temperature, T	T (°C)	23	23	23
	Rt	0.95	0.95	0.95
Velocity, v = q/A	m/s	0.0044	0.0019	0.0007

Type of Flow	Manometer Level (cm)			Time, t (s)
	H1	H2	△H	
Fully Opened	56	42	14	52
Half Opened	84	77	7	122
Slightly Opened	91	85.7	5.3	342



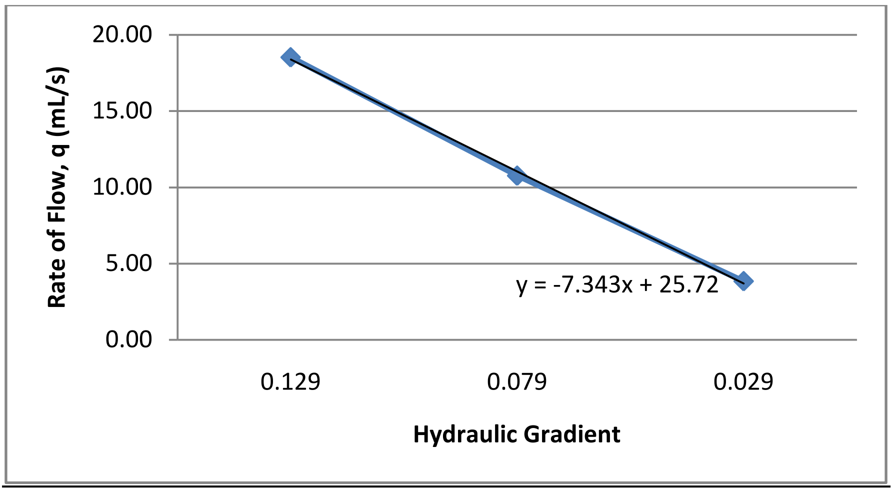
$$k = 1.7181 \times 10^{-3}\ m/s$$

$$\underline{k = 2.0675\ mD}$$

Location 5: Rantau Abang

Test Method : BS1377 : Part 2 : 1990				
Sample Diameter, mm	75			
Sample Length, mm	80			
Area, mm^2	4417.9			
Volume, cm^2	353.5			
Type of Flow		Fully Opened	Half Opened	Slightly Opened
Measure Flow, Q	mL	1000	1000	1000
Rate of Flow, q	mL/s	18.52	10.75	3.83
Height, h	m	0.018	0.011	0.004
Hydraulic Gradient, i=h/y		0.129	0.079	0.029
Temperature, T	T (°C)	23	23	23
	Rt	0.95	0.95	0.95
Velocity, v = q/A	m/s	0.0042	0.0024	0.0009

Type of Flow	Manometer Level (cm)			Time, t (s)
	H1	H2	△H	
Fully Opened	60	42	18	54
Half Opened	82	71	11	93
Slightly Opened	92	88	4	261



$$k = 1.5474 \times 10^{-3}\ m/s$$

$$\underline{k = 1.8621\ mD}$$

4.5 Discussion

Based on the result above, the author manages to draw some conclusion on properties of the sand collected through five different locations.

Firstly, we can find that most of the sand found in the beach or near the beach is well graded sand. This is because of the several geological processes that happen in the beach. The geological process includes wave, tide, saltation, wind (Barusseau, 2011) (Ergin, Karakas, Sozeri, Eser Dogdu, Kadiogu, & Yigit-Faridfathi, 2013). Since, beach is in a open space, the wind energy is quite high other than the wave. Most of the coarse grain sand is deposited from the river into the sea and eroded from rock nearby.

Meanwhile, fine grain sand particle may come from the wind process and wave. The wave process will result in coarse grain sand to settle in while the fine sand to float in the water. However, during low energy wave, the fine sand may settle in. After a long time of the deposition process, the beach may build up leaving a well mix of sand particles. Thus, the high energy depositional environment may contribute to the well graded properties of the sand (Basaham, Gheith, Khawfany, Sharma, & Hashimi, 2013).

On the other hand, sand found nearer to beach is coarser than the sand found far from the beach line. This is showed in the samples taken from Rantau Abang area and Marang. The sand sample from Rantau Abang mainly consists of very coarse to medium sand. This is because the beach in Rantau Abang is open to high wave energy where the fine sand is carried together with the wave leaving behind coarse sand. Meanwhile, the sample from Marang mainly consists of medium to fine sand. This is because; the location is far from the beach line. The sand may have suffered from eolian process, rolling and weathering during the transportation (Manga, Patel, & Dufek, 2011). On top of that, the sand samples taken from Cherating are found to be fine although located near the beach line. This is because; the Cherating beach is more to form of a bay. Thus, the wave energy is quite low to suspend all the fine sand.

In term of roundness, sphericity and permeability, the following table shows the summary of the result;

Location	Mean Sphericity	Mean Roundness	Hydraulic Permeability (mD)
Rantau Abang South	0.69	0.41	2.0929
Rantau Abang North	0.67	0.47	1.5936
Marang	0.67	0.36	2.0675
Rantau Abang	0.72	0.43	1.8621

The author found that most of the sample resulted to be ranging from 0.3-0.5 in roundness and 0.6-0.8 in sphericity. This may due to the age of sand that is still not mature enough. Since, the samples are all taken quite near to the beach the sand may not face enough geological process such as rolling to make it become more rounded. Meanwhile, the value for sphericity is quite high for overall sample. This is because of the depositional environment which the main energy is wave.

In term of the hydraulic permeability, the values for all samples are close to each other where they range from 1.5 – 2.1 mD. These values do not show much of difference since the values of the sphericity and roundness are quite close too. However, the result is not sufficient enough for a proppant testing because the testing conducted for the permability is not a standard testing for proppant (ISO 13503-2 or API RP 60).

4.6 Suitability of the Sand for Proppant

The desired size for sand proppant is 0.41mm – 0.72mm and desired roundness and sphericity is 0.7 (Mohd Saaid, Kamat, & Muhammad, 2011).

From overall result, it is found that the most suitable sample in term of the size are samples from Rantau Abang and Rantau Abang North since they both have dominant particle size ranging from 1.18mm to 0.3mm.

In term of the roundness and sphericity, most of the samples are found to be not suitable for proppant as the result showed a variation from 0.3-0.5 for roundness. On the other hand, the sphericity for all the samples shows a good sign that is ranging from 0.6-0.8.

However, actual suitability is still unknown since we need to simulate the real reservoir condition with actual confining pressure that may reach up to 10 000 psi and actual temperature. Further testing under the real condition is still needed.

4.7 Improvement of the Sand

In term of the improvement, there is several available method described by several author to improve the roundness and sphericity of sand particle. The methods include:

<u>Abrasion</u>

We may simulate the natural process that occur while transportation of particles during sedimentation that is abrasion. During this process, the particle collides with the environment and with each other. Thus, the roundness and sphericity will improve. To do this, we may use the abrasive machine or roller machines that can simulate the abrasion process that occur in nature.

<u>Coat the sand with resin</u>

Coating the sand particle will improve the roundness, sphericity, compressive strength and flow conductivity (Chen, et al., 2012) (Lyle H. Burke, 2012).

CHAPTER 5: CONCLUSION

This project is initiated with a problem statement which is the situation where sand from Malaysia is not fully characterized for proppant uses. As being mention in the introduction part of this report, the objectives of this project is relevance to be conducted considering various factor such as time constraint, facilities and equipment for experiment, and significance of the study. The methodology to reach the objectives and desired result also have been successfully planned and properly executed.

The author is confidence that the objectives are achieved that are; to characterize some of Malaysian sand for proppant, Investigate the suitability of Malaysian sand for proppants in term of its size and roundedness and provide suggestion for any method to improve the properties of the sand for proppant – If there is any.

For the scope of studies, the studies is focusing mainly on the size and roundness characteristic of the sand s taken from suitable location. Although there are several other factors which also should be consider and characterized in order to ensure the suitability of sand to be used as proppant, the factors are being kept constant or on hold due to time limitation. The study also has included the proppant usage in hydraulic stimulation technique. Besides, the location chosen for this project also contain abundant of readily available natural sand.

However, further continuation and experimentation is still needed to be carry on in order to successfully indentify the suitability of Malaysian sand for proppant in various aspects. The important parameters of a proppant such as the closure strength, diagenetic resistance, conductivity and permeability are needed to be tested with the standard testing procedure.

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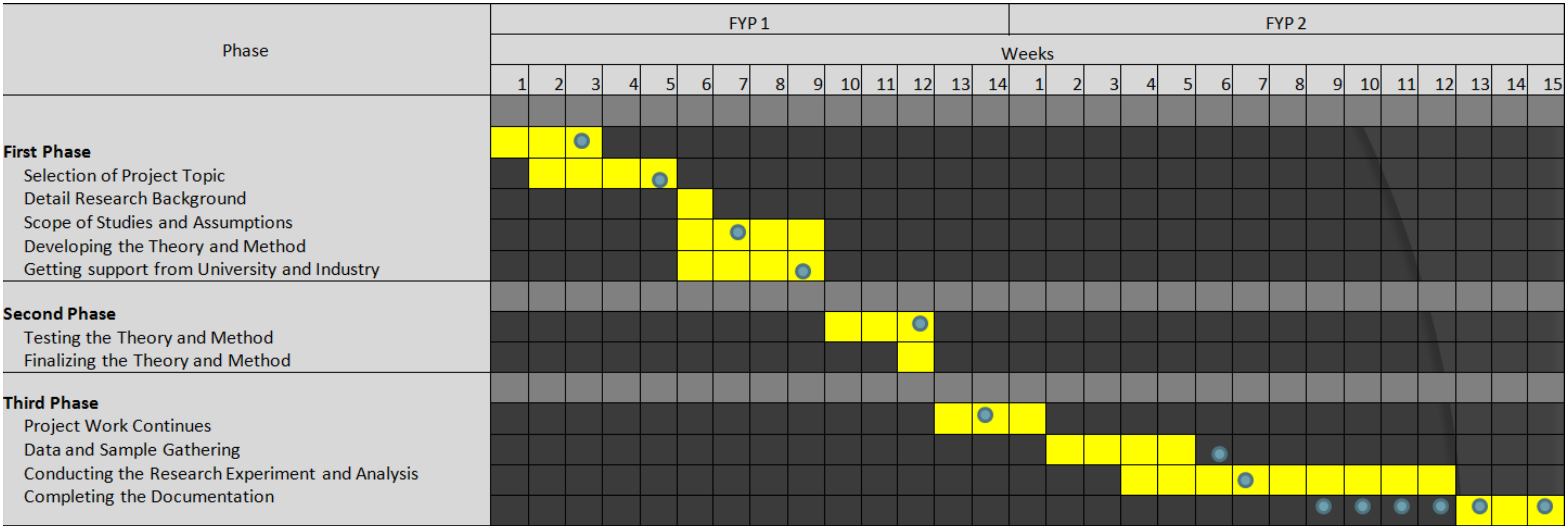
APPENDICES

Appendix I: Gantt Chart



FYP 1

- Project Topic Selected (30th Jan 2013, Week 3)
- Preliminirary Research work done (15th Feb 2013, Week 5)
- Extended Proposal Submitted (27th Feb 2013, Week 7)
- Proposal Defence are carried out (13th Mar 2013, Week 9)
- Tested methodology and Preliminirary Result (5th Apr 2013, Week 12)
- Interim Draft Report Submitted and Discussed (12th Apr 2013, Week 13)
- Interim Report Submitted (19th Apr 2013, Week 14)

FYP 2

- Data and Sample Fully Gathered (21st Jun 2013, Week 6)
- Progress Report Submitted (28th Jun 2013, Week 7)
- Result Obtained (12th Jul 2013, Week 9)
- Pre-Sedex (19th Jul 2013, Week 10)
- Draft Report Submitted (26th Jul 2013, Week 11)
- Dissertation (soft bound) Submitted (2nd Aug 2013, Week 12)
- Technical Paper Submitted (2nd Aug 2013, Week 12)
- Oral Presentation Conducted (9th Aug 2013, Week 13)
- Project Dissertation (hard bound) Submitted (23rd Aug 2013, Week 15)

Appendix II: Location Map

Cherating

Rantau Abang (South)

Rantau Abang

Rantau Abang (North)

Marang

Appendix III: Location Layout

Cherating

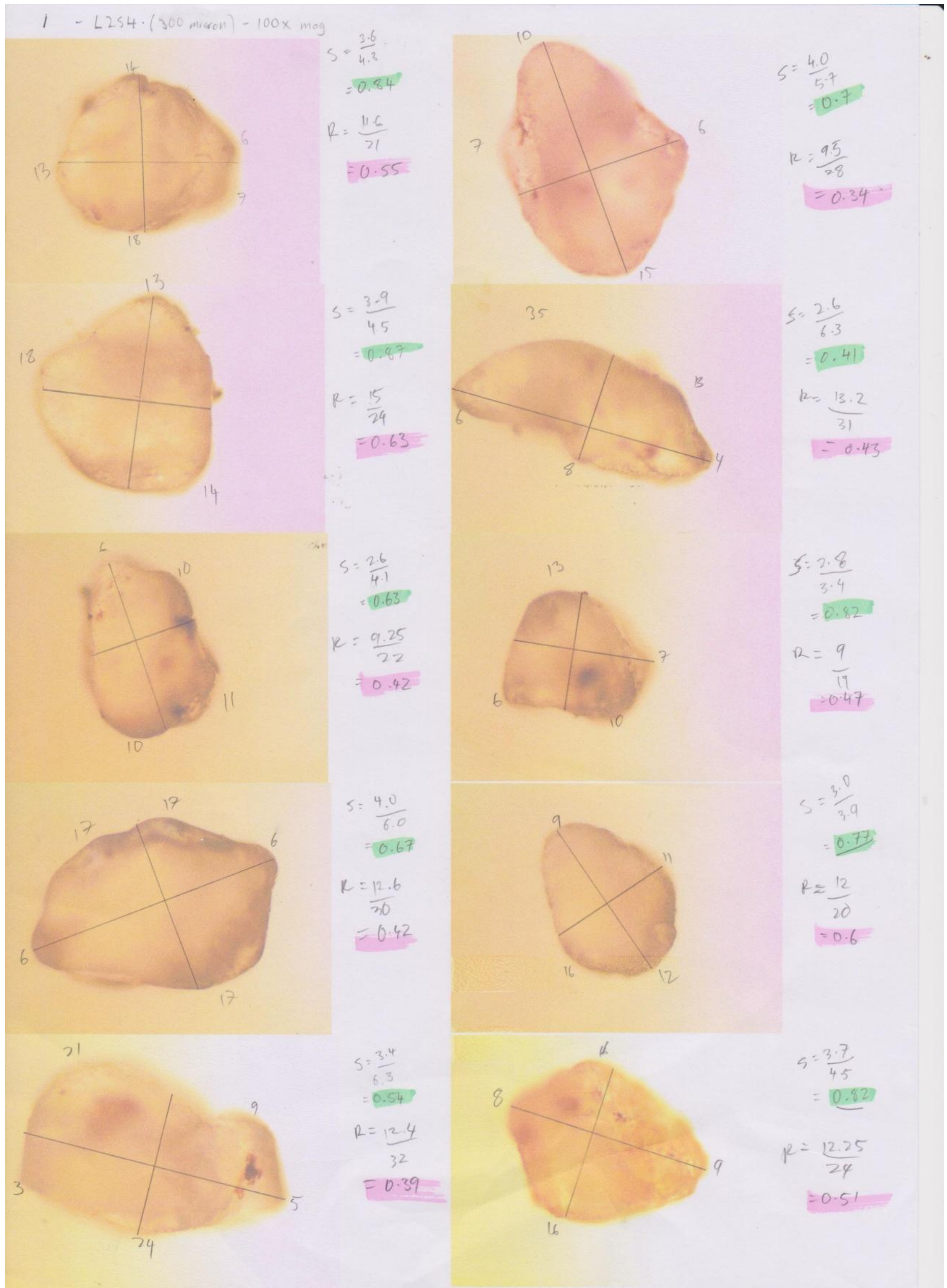
Rantau Abang (South)

Rantau Abang

Rantau Abang (North)

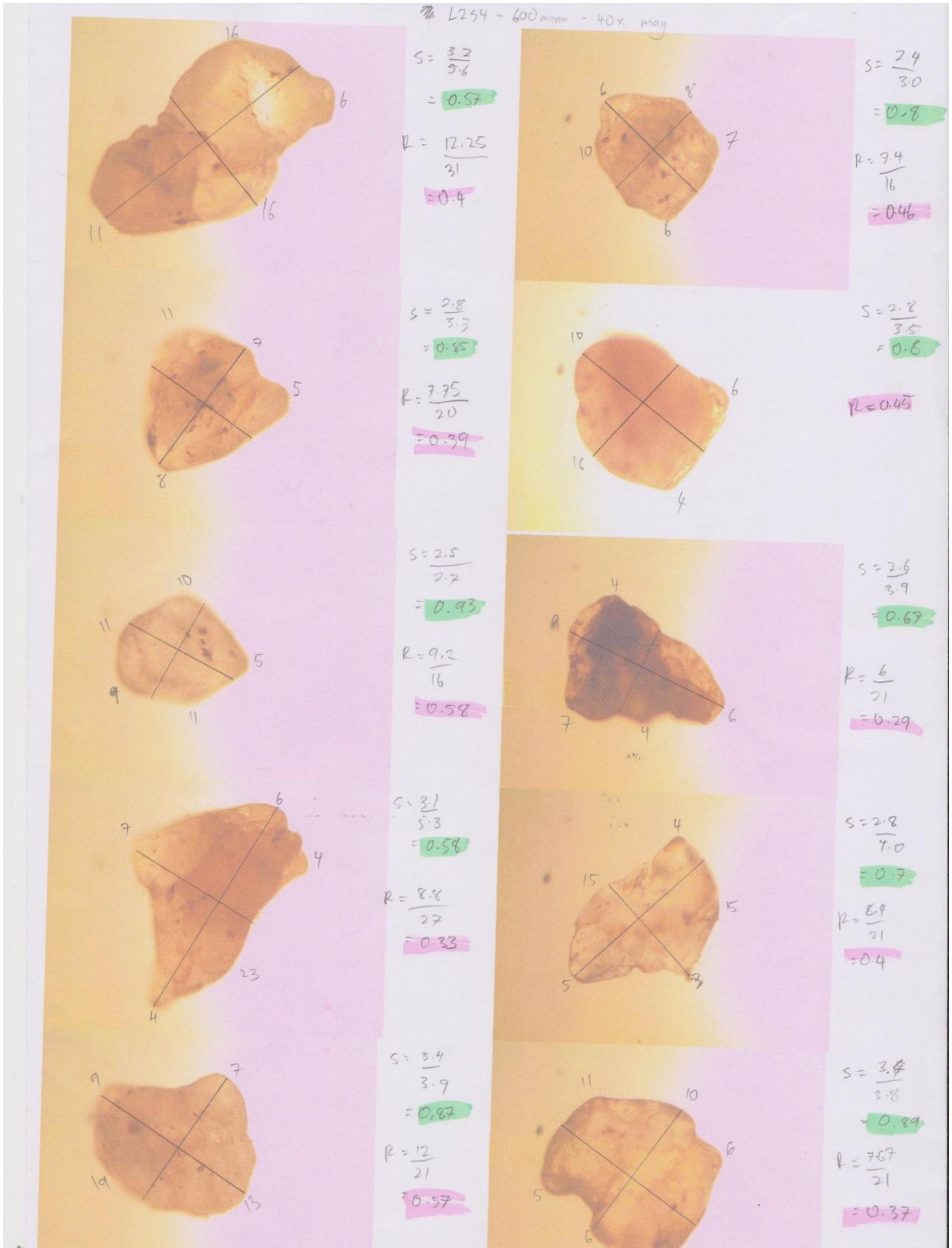
Marang

Appendix IV: Manual Hand Calculation for Roundness and Sphericity

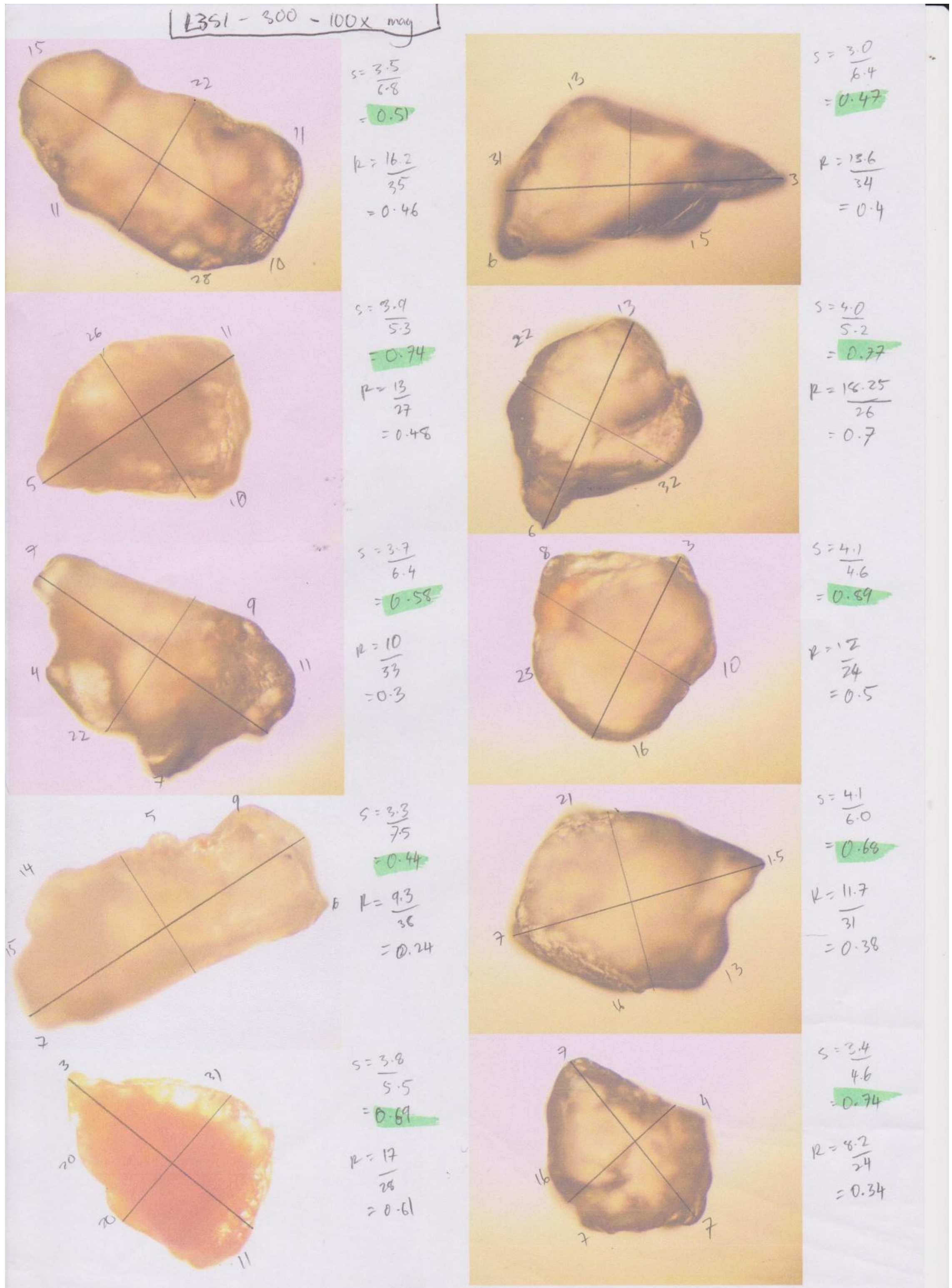


1. Sample L2S4 - 300 micron - 100x magnification

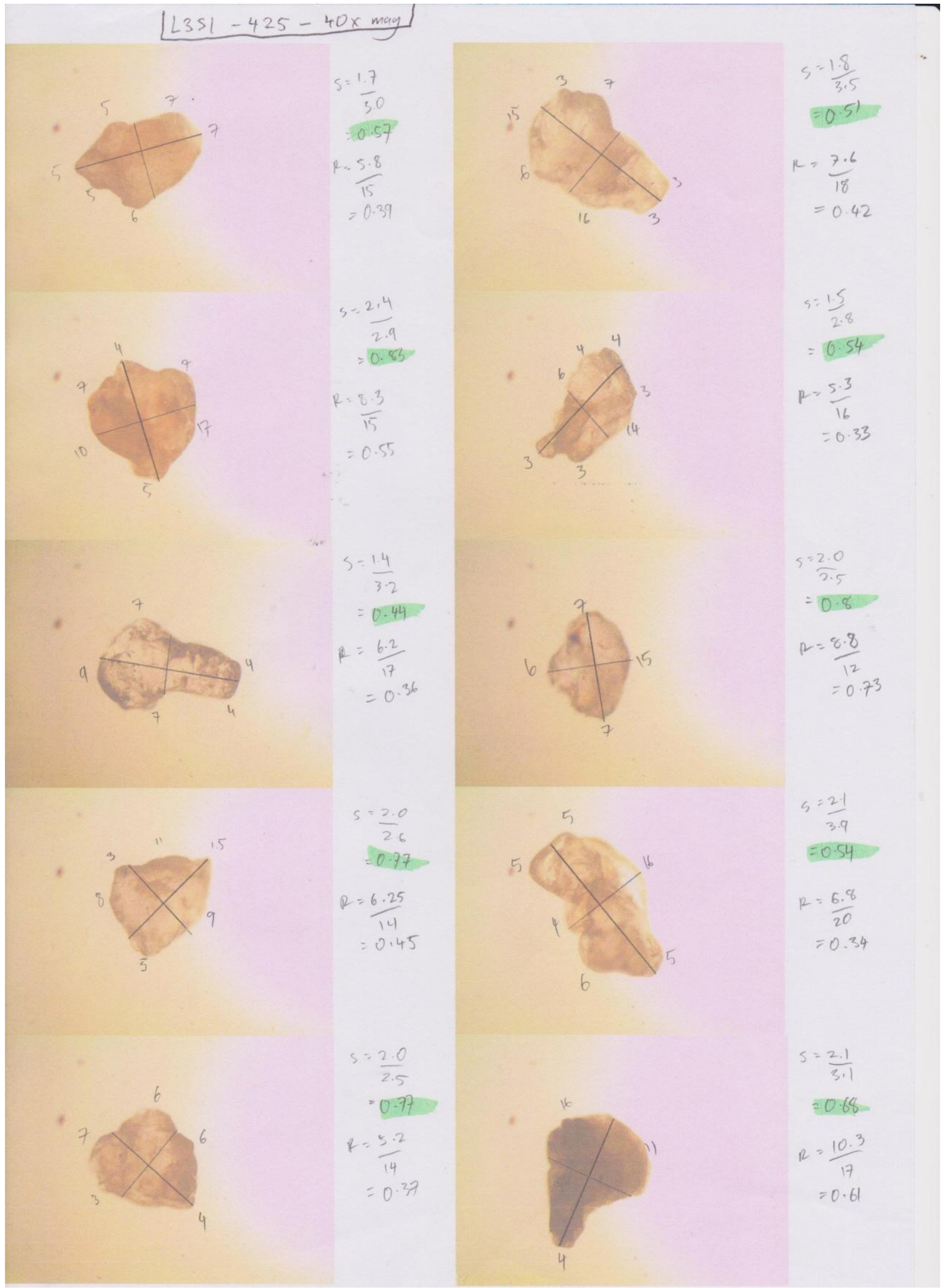
2. Sample L2S4 - 425 microns - 40x magnification



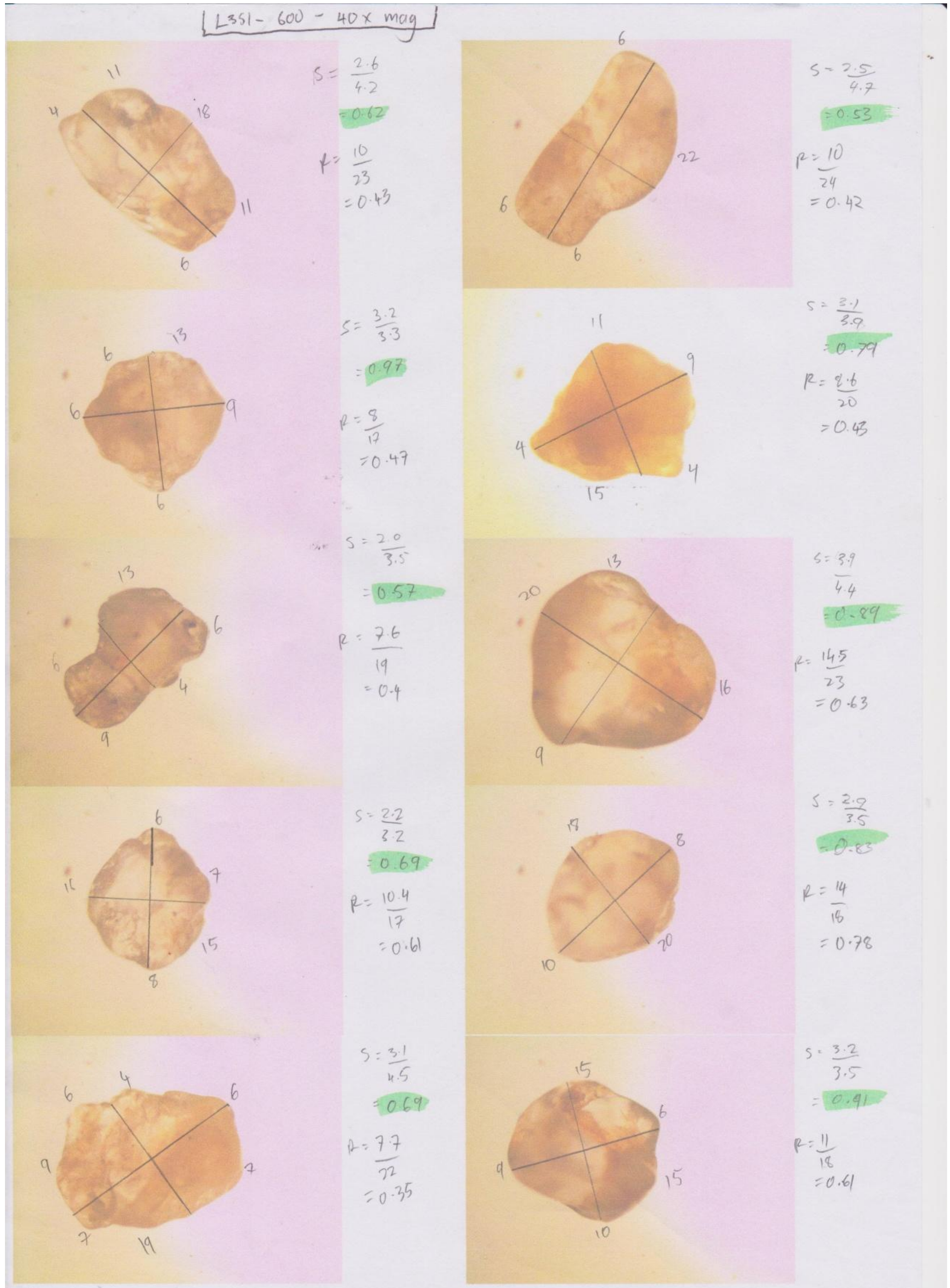
3. Sample L2S4 - 600 microns - 40x magnification



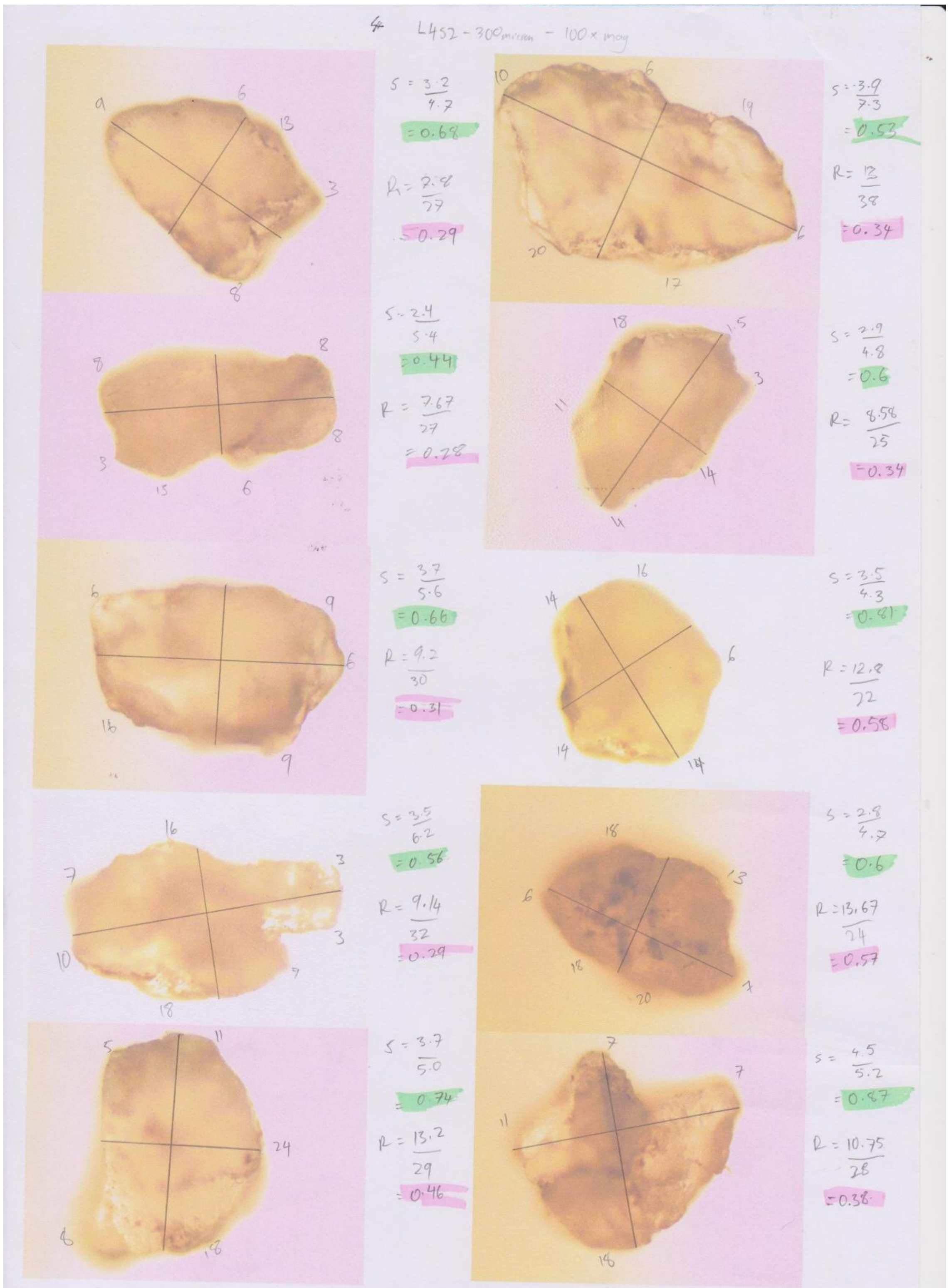
4. Sample L3S1 - 300 microns - 100x magnification



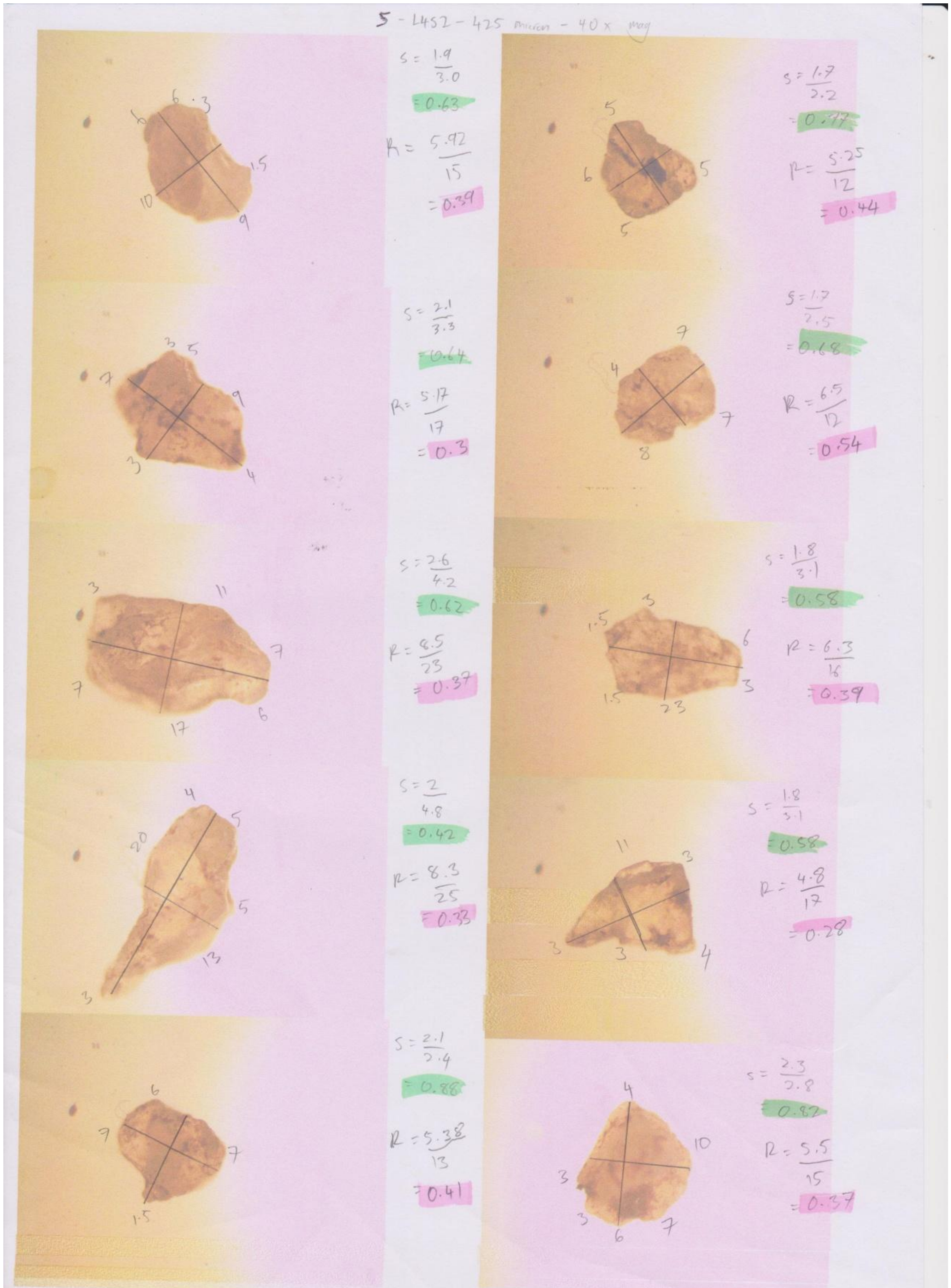
5. Sample L3S1 - 425 microns - 40x magnification



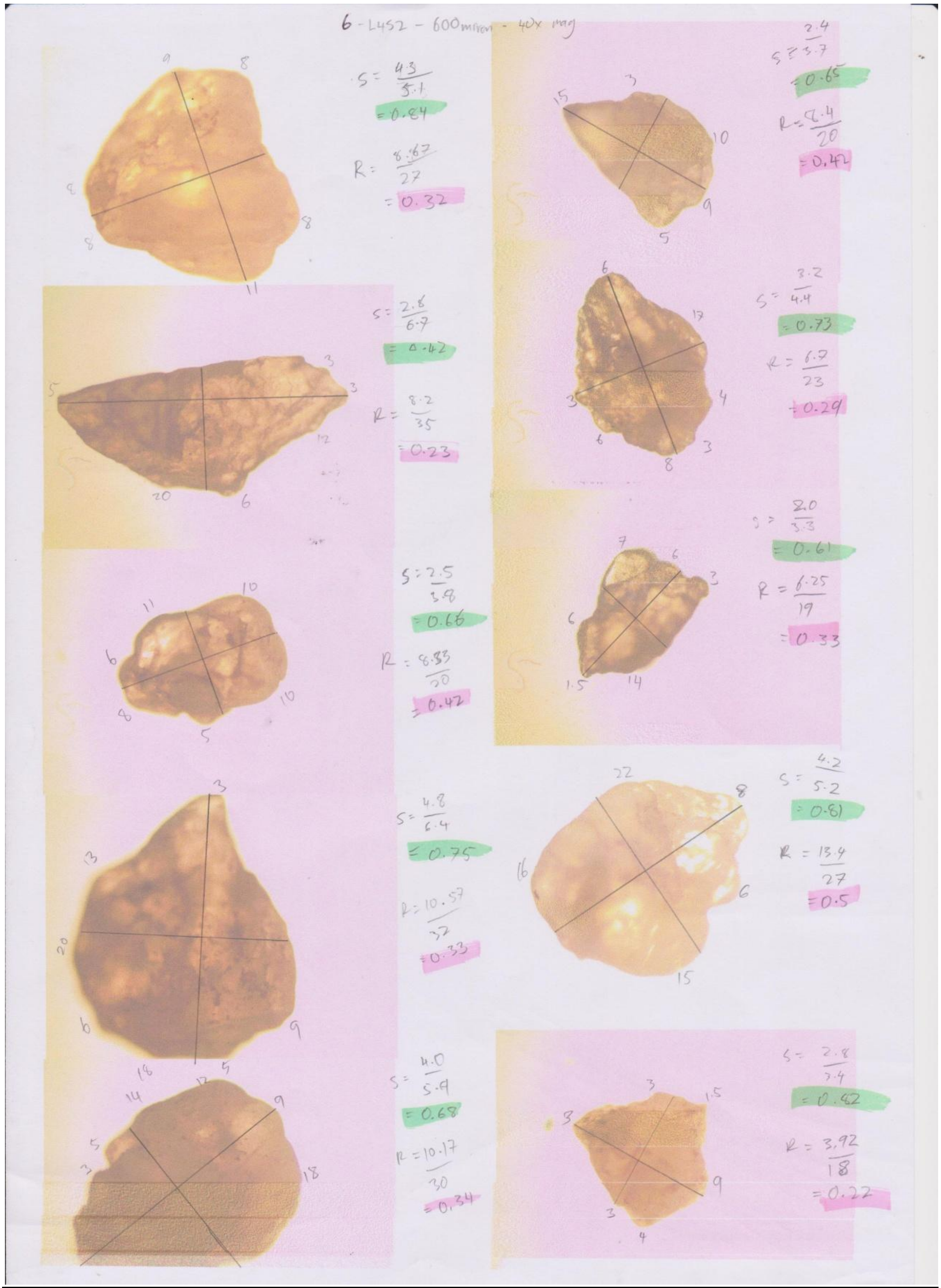
6. Sample L3S1 - 600 micron - 40x magnification



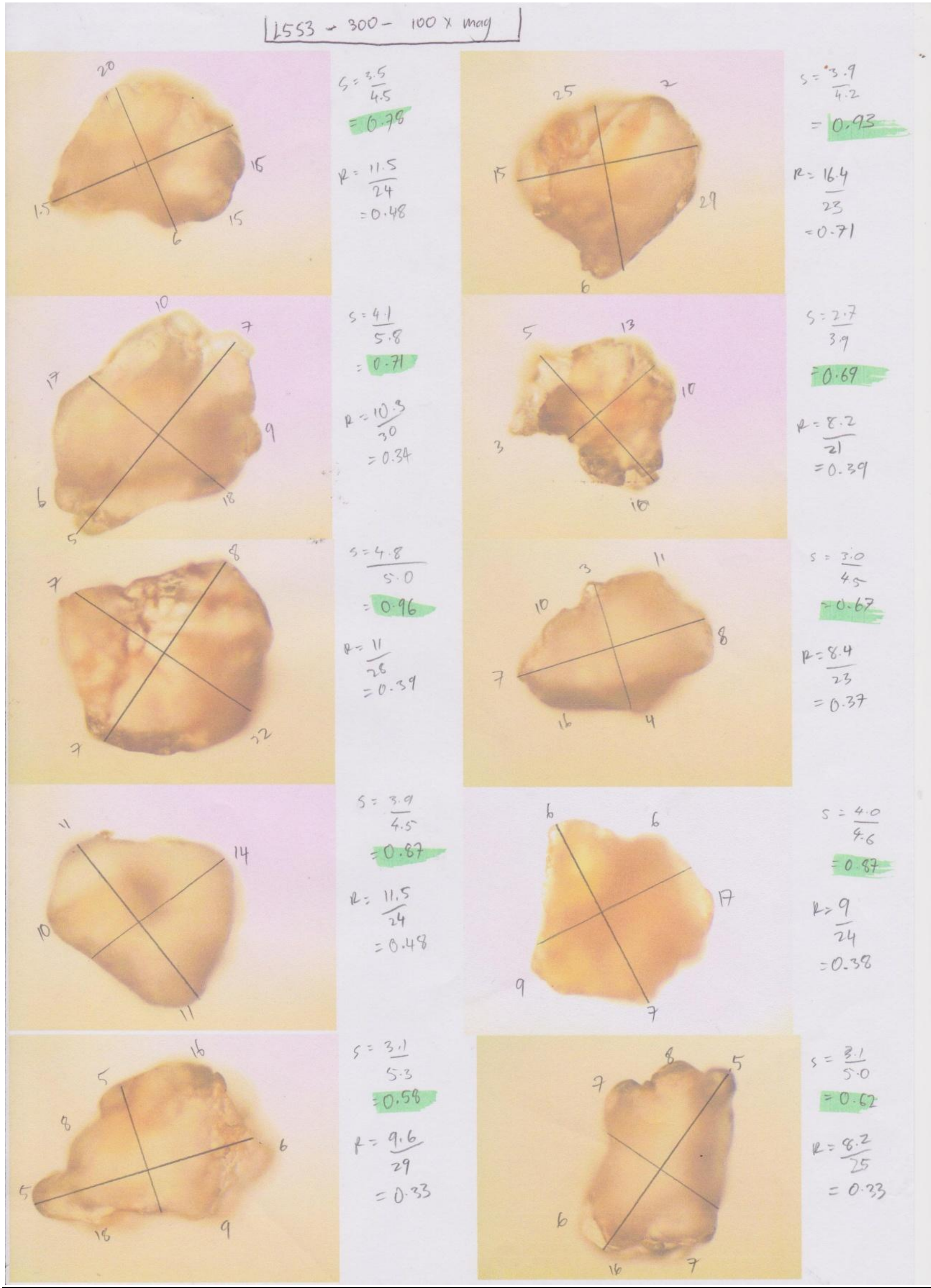
7. Sample L4S2 - 300 micron - 100x magnification



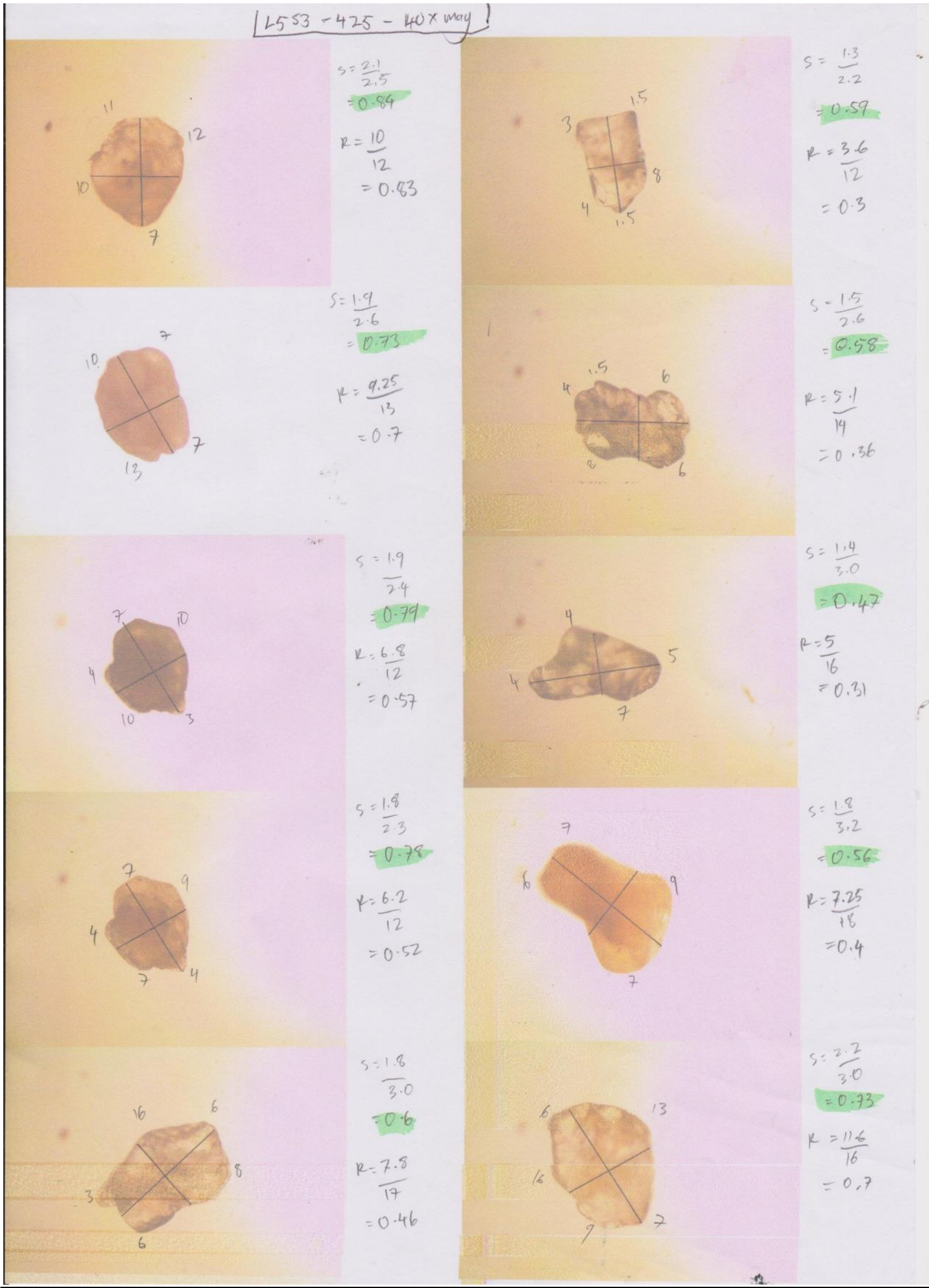
8. Sample L4S2 - 425 micron - 40x magnification



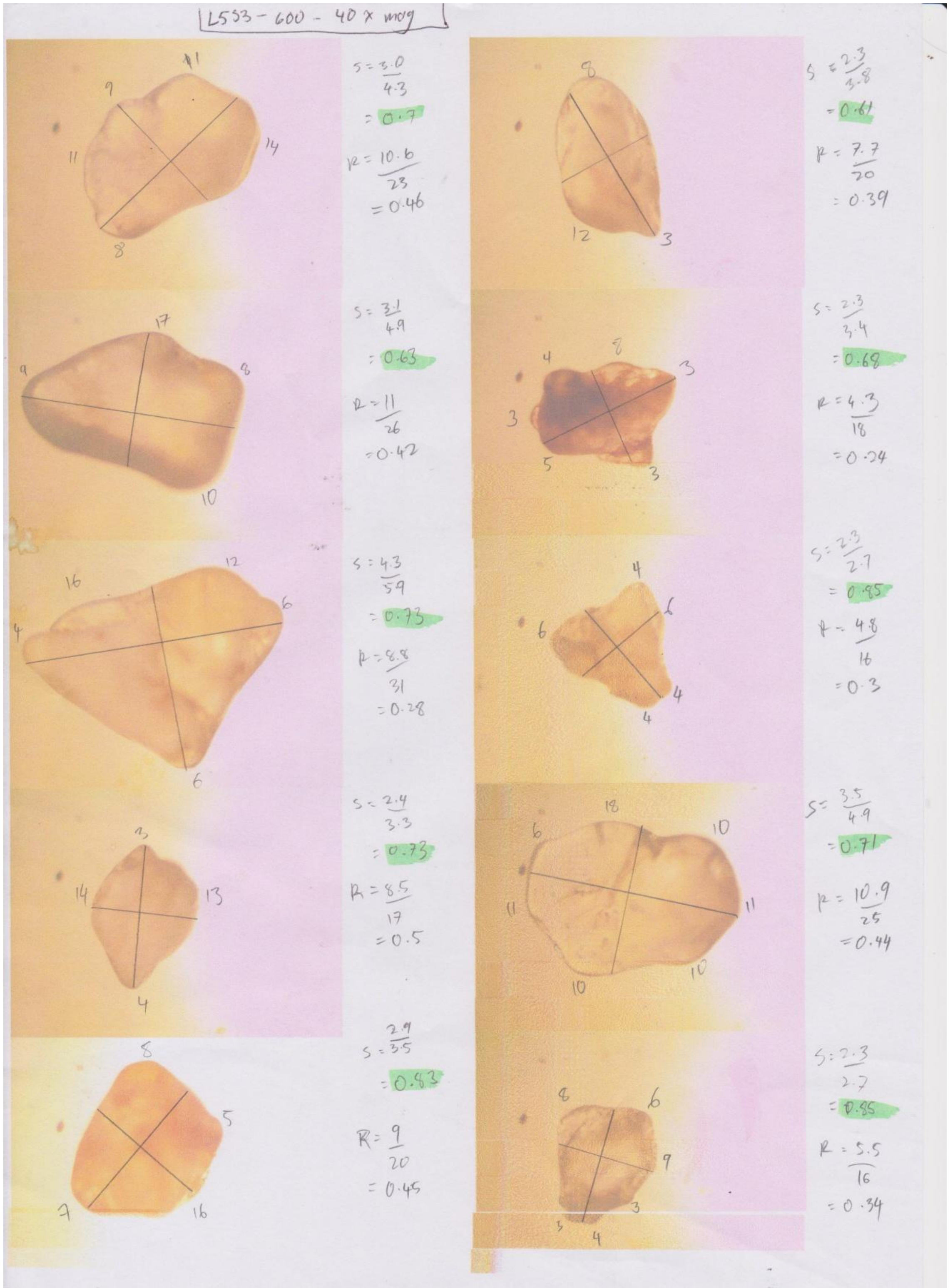
9. Sample L4S2 - 600 micron - 40x magnification



10. Sample L5S3 - 300 micron - 100x magnification



<u>11</u>. Sample L5S3 - 425 micron - 40x magnification



12. Sample L5S3 - 600 micron - 40x magnification